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The Paris Fire Department: Its Latest Equipment

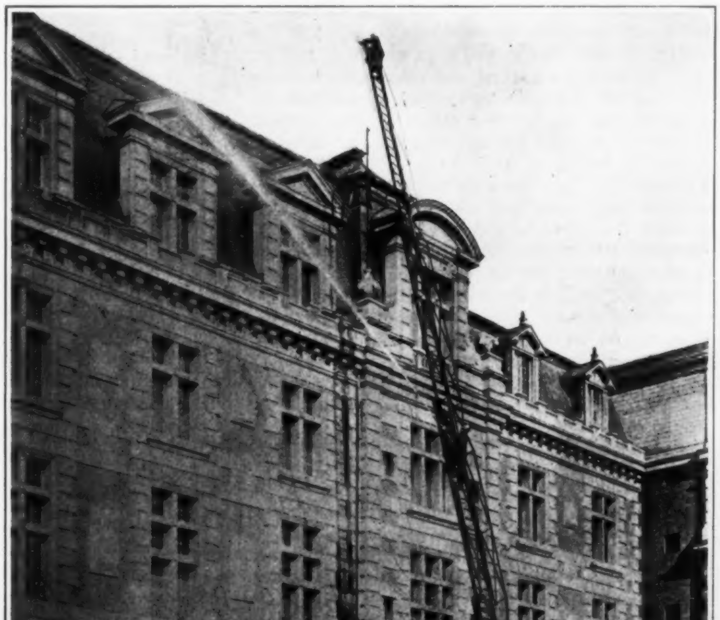
The Fire Department of the French capital has recently introduced radical changes in its equipment of fire engines and other motor-driven fire appliances, bringing its entire outfit thoroughly up-to-date. Until a short while ago electric automobiles had been employed, but experience has shown that gasoline motors are better adapted for the purposes in view, so that at the present time practically all the motor-driven cars are of the gasoline type. In some cases, however, small dynamos are carried on the trucks to furnish current for searchlights or for operating certain of the appliances such as the new extension ladders. There are four principal types of vehicles in service. The first of these is known as the auto pump. This serves a double purpose, not only carrying the fire engine, but also accommodating a two-wheel ladder truck, which is taken bodily on board the car and can be let down on the ground on reaching the site of the fire. The ladder truck itself is comparatively small, so that it can gain admission in narrow passages which

(Continued on page 261.)

Each Pump of the New Equipment is Sufficiently Powerful to Serve Three Lines of Large-Nozzle Hose or Six Lines With Small Nozzles.

Self-supporting Turntable Ladder Car. This is a Special Form of Extensible Ladder Permanently Carried on Board a Motor Truck

When inclined at an angle of 76 Degrees and Extended to Its Full Length of Eighty Feet, this Ladder is Capable of Sustaining a Weight of 500 Pounds at Its Upper Extremity.



Firemen's Ladder Extended Directly from Its Supporting Motor Truck. The Ladder Which is Shown in Near View in the Illustration Above is Here Seen in its Extended Working Position.

LATEST EQUIPMENT OF THE PARIS FIRE DEPARTMENT.

Downwardly Converging Tandem Planes

A Promising Development on the Basis of Eiffel's Work

By Robert D. Andrews

The brief report upon "tandem planes" made by M. Eiffel in the second edition of his monumental work on "The Resistance of the Air and Aviation," is remarkable for many reasons. For one thing it proves that at last a means has been found for giving a following plane its full efficiency. In addition, there is precise information regarding the movements of the center of pressure upon downwardly converging tandem planes, which is of great significance. But even more noteworthy are the logically involved evidences of a dynamic relation between front and rear planes of this description whose existence seems hitherto to have escaped general attention. While M. Eiffel states that he has only sketched out these systems and expects to continue his experiments upon them, sufficient data are given to enable us to draw some very interesting conclusions leading to the final inference that in the tandem arrangement of downwardly converging planes are found a number of the requisites of the ideal aeroplane. On this account it is of value to develop the information we have in some detail.

M. Eiffel's experiments on tandem planes included three different arrangements or "systems," as he calls them. In each two similar planes were used, of circular curvature, with the depth of the chord 1/13.5 of its length. Each plane measured 15 by 90 centimeters, and they were spaced 30 centimeters apart. In System I, the chords of the two planes were in a straight line. In System II, the rear plane was tilted forward at a negative angle of 2.5 degrees. In System III, the rear plane had a negative angle of 5 degrees. See diagram.

The planes used are identical with that which M. Eiffel has found by comparison with many others to be most generally efficient and which he has adopted in his report as a standard for estimating relative values. It is designated Wing No. 3. In his chart of curves, giving the results of the tandem experiments, the curve of this standard 1/13.5 surface as a monoplane is also plotted. Since in these charts all results are reduced to common terms per unit of supporting surface, a comparison of surfaces of different areas is made possible. In addition to the charts, there are given in the annex the figured resultants of each system of tandem planes. By reference to these and the resultants of the single standard plane, we are enabled to calculate the parts performed by the rear planes of each system. We know what the front surface does when taken alone, and what both surfaces do in conjunction; hence, we find at once the work done by the rear surface. The facts thus brought to light are so extraordinary that they merit the closest attention.

We quote below from M. Eiffel's tables showing the drift (R_x) and the lift (R_y) and the ratio between them (R_x/R_y) of the three systems, with the wind striking below the front plane at the successive angles of 3, 6, 9, and 12 degrees. The unit of resistance is 1 gramme per square meter of surface.

TABLE I.—ANGLE OF INCIDENCE FOR FRONT PLANE.

System I. No Convergence.

	3 deg.	6 deg.	9 deg.	12 deg.
Drift	123	155	211	274
Lift	665	987	1,315	1,540
Ratio	.19	.16	.16	.18

System II. 2.5 deg. Convergence Downward.

	3 deg.	6 deg.	9 deg.	12 deg.
Drift	141	167	219	291
Lift	1,094	1,568	2,068	2,326
Ratio	.13	.11	.11	.12

System III. 5 deg. Convergence Downward.

	3 deg.	6 deg.	9 deg.	12 deg.
Drift	129	145	181	246
Lift	334	703	965	1,347
Ratio	.39	.21	.19	.18

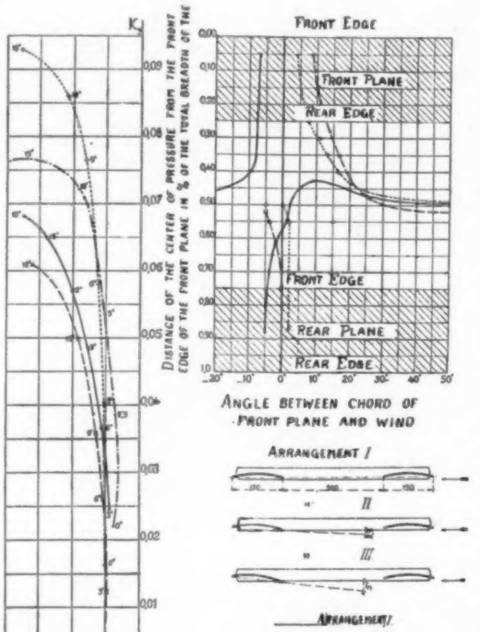
Since comparison shows that there is no very striking difference in the amounts of drift for the three systems, while their lifts vary in an extraordinary way, we will combine the latter in another table for more careful examination, recurring later to the matter of drift.

This table brings out the very curious fact that System II, which is mediate to the two others, exceeds them greatly in lifting power, carrying, in an average of positions, half as much again as System I, and twice as much as System III. Furthermore, when we remember that for the same angle of incidence, the front planes of each system are doing exactly the same amount

TABLE II.

	Angle of Incidence. Deg.	No Convergence, System I	2.5° Convergence, System II	5° Convergence, System III
Lift at	3	665	1,094	334
	6	987	1,568	703
	9	1,315	2,068	965
	12	1,540	2,326	1,347
Total	....	4,507	7,056	3,349
Average	....	1,127	1,764	837
Percentage	....	.64	1.00	.47

of work, and that *the inequality of total result is due solely to the positioning of the rear planes*, the significance of these facts becomes yet more impressive. In the next table are shown the parts performed by the front and rear planes, respectively, of System II. This is done by employing for the front plane at the successive



Eiffel's Diagram of Lift and Drift and Center of Pressure.

angles indicated, the values belonging to this plane when used alone as Wing No. 3.

TABLE III.

System II.	2.5° Convergence Degrees.	Both Planes.	Front Plane.	Rear Plane.	Relative Lift of Rear Plane.
Lift at	3	1,094	567	527	— 40
	6	1,568	783	785	+ 2
	9	2,068	931	1,137	+206
	12	2,326	1,019	1,307	+288
Total	..	7,056	3,300	3,756	+456
Average	..	1,764	825	939	+114
Percentage	..	....	1.00	1.13	......

Lift (R_y) of the two planes in System II.

Incredible as the conclusions of the above table appear, they follow as a mathematical necessity from the data established by M. Eiffel. The table shows that for an average of positions of from 3 to 12 degrees of incidence *the lifting power of the rear plane is increased by 13 per cent over that of the front plane*, when these are disposed as in System II.

Now let us consider the *variations of lift by the rear plane* which would occur if the planes were first set in the position of System I and the rear plane were moved successively to the positions it occupies in the other systems, i. e., to the negative angles of 2.5 and 5 degrees. We will assume that the wind has a constant angle of incidence relative to the front plane of 3 degrees. Using as a constant for the lift of the front plane the value above employed, 567, we may construct table IV.

TABLE IV.

Table of Lifts with wind constant at 3 degrees incidence and the rear plane at different angles of adjustment.

Lift with Rear Plane, as in	Both Planes.	Front Plane.	Rear Plane.
System I. No convergence	665	567	98
System II. 2.5 degrees convergence	1,094	567	527
System III. 5 degrees convergence	334	567	—233

Here we find that as the rear plane is tilted forward from 0 to —2.5 degrees, the lift increases enormously, to more than 500 per cent. Continue the inclination 2.5 degrees more, and the lift wholly disappears and a downward pressure ot 233 units takes its place. *There is, therefore, a mean position for the rear plane where its lift greatly exceeds that of the positions closely adjoining.* This phenomenon is so unusual in nature and so marked in degree, that it imperatively challenges a solution. There is every reason to suppose that it is a product of the effect induced in the air by its contact with the front plane; but the precise character ot this effect and of the operation that ensues from it is not at first evident. That this phenomenon is due to the spatial relation of the two planes and is independent of the angle of flight is shown by the clear superiority of lift shown by System II over the others at all angles. In the opinion of the writer, an explanation may be found in the *elastic reaction* of the air to the passage of the front plane.

An elastic body is one which actively resists distortion of its normal form, which is only another way of saying that its molecular particles tend to retain and regain when lost their normal spatial distribution. Work must be done to crowd them together or pull them more apart. Conversely, where such work has been done, a nearly equal amount of work will be done by the return of the particles to their normal positions. This truth is exemplified by the steel spring, the billiard table cushion, and a host of other material things possessing elasticity.

When air in motion comes in contact with a fixed inclined plane, as in the Eiffel experiments, there ensues a rarification or tension of the air above the plane, and a compression below it. As the mass of air passes beyond the plane, these two areas oppositely affected are left in direct conjunction. The lower area seeks relief from its state of compression by expansion in the direction of least resistance, which is upward. The energy of this movement carries it beyond its level of inception and results in an inversion of the primary condition, so that the upper area becomes compressed and the lower is put in tension. This vibration back and forth continues until the energy of reaction left in the air by the plane has become dissipated. These vibrations in the moving air, could they be seen instantaneously, would appear as a continuous wave issuing from the rear edge of the plane, and are so shown in Diagram 5.

Now suppose that a second plane $C—D$, identical with $A—B$ but reversed, be placed at the same level with it and so that its front edge coincides with the wave line which marks the border between the oppositely affected areas, as shown in Diagram 6. Expressing tension and compression by the signs minus (—) and plus (+), it becomes evident that under

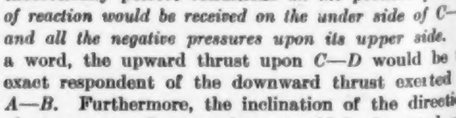


Diagram 5.

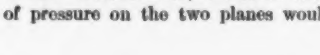


Diagram 6

theoretically perfect conditions *all the positive pressure of reaction would be received on the under side of C—D, and all the negative pressures upon its upper side.* In a word, the upward thrust upon $C—D$ would be the exact respondent of the downward thrust excited by $A—B$. Furthermore, the inclination of the direction of pressure on the two planes would be inverted, and

as the pressure is a retarding force upon the first plane, it appears as an accelerating force upon the second. The second plane is virtually gliding upon an ascending current.

It seems evident that under theoretically perfect conditions all the energy of reaction left in the air by the first plane would in this way be captured and utilized by the second, in which case there would be no loss of energy to the air. Of course this is practically impossible; but the thesis shows how any deviation from a right positioning of the second plane necessitates a loss of supporting efficiency. *If the wave line passes above or below the second plane, relative failure ensues.* This is what we may suppose to occur in Systems I and III of M. Eiffel's experiments. In Table I the wave line passes below the rear plane; in Table III it passes above; while the efficiency of Table II is seemingly due to the fact that the wave line fairly meets it at its front edge.

This theory of elastic reaction of course cannot be regarded as any thing but a suggestion made to meet certain facts already familiar to the writer before tandem planes were made the subject of experiment by M. Eiffel. The behavior of free gliding models almost identical in fore and aft section with Eiffel's No. II is a convincing proof that some sort of interrelation of an unusual nature exists between the two planes. The matter seems deserving of the most careful investigation by physicists as well as engineers.

Let us pass now to a brief consideration of the movements of the center of pressure upon a system of downwardly converging tandem planes. M. Eiffel shows that upon such a system as a single whole the center of pressure advances continuously as the angle of incidence is lessened, until a point is reached when it passes above the front edge and assumes a position upon the top of the rear surface. It is evident upon reflection that in such a system as Table II there is an intermediate condition when the front surface is receiving an upward pressure and the rear surface a downward pressure. But whatever the pressure or couple of pressures, they tend to the inherent stability of such a system in free flight. In his earlier report upon what he calls Wing No. 2, a plane of 1/27 depth of chord and circular curvature, M. Eiffel shows the position of the center of pressure upon this surface at all possible angles throughout 360 degrees. Thus, we find it presented in positions where its concave side is upward, and here we find the center of pressure behaving in precisely the same way as in System II above, running way forward to the extreme front edge below and then passing back to the rear above. It is evident therefore that this behavior of the centers of pressure upon downwardly converging tandem planes is not accidental but is inherent in that convergent relation, since it is consistently manifested when that relation occurs, and is manifested under no other known conditions. *It should be noted, also, that in System I, where there is no downward convergence of the planes, the center of pressure returns toward the rear edge as if the system were an ordinary monoplane.*

In regard to the matter of drift, earlier set aside, there is no evidence for believing, and some for not believing, that the planes of constant curvature employed by M. Eiffel as tandem planes are better fitted to such use than planes of a parabolic or elliptical section, and that it is not improbable that in his further study of this subject the detrimental drift at low angles recorded by him may be reduced.

We may summarize these conclusions as follows:

Downwardly converging tandem planes give promise of securing from the air a larger measure of support for a given expenditure of propulsive energy than any form or system of surfaces now known. At the same time, since the behavior of the centers of pressure upon them is what it should be ideally for the fullest possible degree of fore and aft stability, while in this respect all existing aeroplanes are conspicuously deficient, it would seem that this system of surfaces is destined to supplant existing types of aeroplanes for general purposes.

NOTE BY DR. A. F. ZAHM.

Mr. Andrews' analysis of Eiffel's tandem monoplane experiments discloses some interesting relations based on the assumption that the forward surface, at a given speed and incidence, always encounters the same impactual pressure, whatever be the inclination of the rear one, and whether it be present or absent. This assumption, though in general not valid, may be approximately correct in the given instance.

To explain the remarkable wind force on the rear plane in Eiffel's experiment, Mr. Andrews surmises that the air stream passing the front plane generates and transmits to the rear one a compressional wave like that of sound, and this he illustrates by a horizontal wavy line. Thus while the air particles streaming along the surface of the front plane are diverted downward and may pass well below the rear plane, a part of their energy may by molecular impulse be transmitted to the particles streaming past the rear plane, and there exercise a marked effect on the surface pressure.

This molecular-transmission hypothesis of Mr. Andrews, to explain the increase of lift on the rear plane, differs essentially from the molar-rebound theory which assumes that the air stream emerging from the front plane rebounds *en masse*, and so exerts the observed effect on the rear plane. In 1893, Prof. J. J. Montgomery, one of the numerous reinventors of Boulton's three-torque control for aeroplane, informed the Aeronautical Conference at Chicago that he had allowed thistle down to float past an inclined plane in the open wind, and had observed that after passing the plane it pursued a course distinctly wavy as compared with its line of approach. At a rather earlier date the present writer observed that, as required by theory, the wae from a down-arched horizontal wing also inclines rearwardly downward. A wavy line drawn obliquely downward with diminishing amplitude best indicates the observed phenomenon. Both these characteristics of the wake, its vabratoriness and its obliquity, were graphically recorded by Prof. Marey, by use of smoke streams and a camera, as shown in the SCIENTIFIC AMERICAN for February 1st, 1902. These records show also the varying stress in the wake by the varying thickness of its marginal smoke stream-lines. The pulsatory variation of the air stress from point to point along a wing contour line from front to rear edge, on both the face and back of arched and plane surfaces inclined to a steady stream, is shown admirably in Eiffel's pressure diagrams for single surfaces exposed to a uniform wind.

The utilization of the "rebound" here in question has been a favorite scheme with many inventors, though they have been groping intuitively, instead of using Eiffel's illuminating quantitative method of ascertaining the much needed facts upon which rationally to base a practical invention. One plan has been to give the wing a reverse[1] curve toward its rear; another has been to use an elastic trailing edge, as in Etrich's monoplane. Some years ago an inventor showed me a tandem arrangement of propeller blades in which the following blade was to be so positioned as to recover some of the energy expended by its forward mate. Perhaps some one will explain that ducks fly in tandem, or in V ranks, partly for the same reason. More than a decade ago Mr. Mattullath contended that many birds catch with their tails the rebounding wake from their bodies and wing bases.

Mr. Andrews' ingenious analysis and suggestions, as also the speculations of unnumbered earnest and meritorious inventors, show the extreme demand for an institute in America where all questions in the basic science of aërial locomotion can be investigated by a staff of qualified specialists having the facilities of a laboratory like that of Eiffel, or several others of ample endowment in European countries. It was unfortunate for American prestige in aviation when Langley's aerodynamic experiments at the Smithsonian Institution were subjected to official secrecy, and finally discontinued for lack of funds.

[1] The modern type of wing reversely curved at its rear, like a bird's wing under heavy sustaining pressure, was proposed for a practical aeroplane, on account of its superior longitudinal stability, by Maj. J. D. Fullerton, R. E. (coiner of the terms "lift" and "drift") in a paper read before the aeronautical congress held in Chicago in 1893. Turnbull in 1907, and Eiffel four years later, studied Fullerton's wing profile, and both commended its stability; but Eiffel found its lift-thrust ratio small as compared with that of standard forms. At fine incidences the center of lift is at the front edge of the wing, showing obviously that at some points further back the resultant unit pressure must be downward—a costly distribution apparently.

Power from Powdered Peat*

By Dr. J. McWilliam

THIS subject has been given a new interest from the exhaustive experiments of Lieut. Ekelund in Europe, and as I had used powdered peat to produce power at my peat factory near London, Canada, for two seasons four years ago, I have been requested to give a short paper on the subject in order to bring before the society the possibilities that are contained in this method of obtaining energy to drive machinery.

Lieut. Ekelund states that a ton of powdered peat containing about 15 per cent moisture is quite equal in heat units to a ton of good soft coal, and, if properly applied, will go as far in raising steam as a ton of coal. Usually a ton of good soft coal is looked upon as equal to 1.8 tons of peat, that is air-dried machined peat. But Lieut. Ekelund claims that the combustion is so much more complete and the amount of air required is so much less in amount that the above result is obtained. The larger amount of air required in the combustion of a ton of coal has such a cooling effect on the boiler that much of the heat of the coal is lost, whereas the smaller amount of air required for the complete combustion of peat allows all the heat energy of the fuel to be delivered to the boiler.

Assuming that this is a fact that a ton of powdered peat is equal in heat giving properties, or nearly equal, to a ton of soft coal, then the method of obtaining powdered peat of a moisture content of 5 per cent to 15 per cent becomes a very important matter.

Lieut. Ekelund describes his method of digging the peat and air-drying it, of harvesting it in the form of blocks, at from 30 per cent to 50 per cent moisture content, according to the weather prevailing during a given season. At this point in the preparation of peat powder he describes methods of grinding, etc., which he has discarded, but does not tell us how he grinds it now, nor how he dries the powder to the point where it is an efficient fuel. As I have had some experience in grinding peat, and also in grinding peat powder, I am extremely curious to know the details of his method of grinding peat and also of applying heat to dry it. Had I those details I would have been in a much better position to calculate the cost of the whole scheme if carried out in our country. This grinding and drying of peat with 25 per cent to 50 per cent of water is a most difficult procedure. I cannot understand how he can grind it into a fine powder when it is so wet. Of course, he says he does it, and until we get a description of his pulverizing apparatus we must leave the matter there. He also says he dries it to 15 per cent moisture; granted that it is ground fine enough, I believe this can be done, but it is difficult, and a detailed account of his drier would interest me very much.

Our own experience with collecting and drying peat powder by the Milne machine has been satisfactory, and from the first, has been commercially successful. We harrow the surface of the bog, exposing the broken peat to the influence of the sun and wind, which, in favorable weather, very quickly reduces a thin layer of peat to a moisture content of 25 per cent to 40 per cent. Over this prepared surface we pass a suction fan collector, which sucks up the dry material and leaves the wet. The peat is placed in our storehouse by this means as a finely divided powder, nearly all of it fine enough for use as a fuel under a boiler as applied by Lieut. Ekelund. Thus, by simply harrowing the bog and then sucking up the dust, we harvest our peat and grind it at one operation, also drying it to 25 per cent to 40 per cent moisture. All the expense of digging, stacking, carting and grinding being thus finished in a single operation. We have no absolute details of the cost of collecting a ton of this powder in this way, although many attempts have been made to get at the actual outlay. I never was quite satisfied, however, that every item of expense was included, and until we come to run commercially it will be difficult to give an accurate statement. This much is certain, that we can put this powder in our storehouse at less than 75 cents per ton—which, in this country of high wages is much better than Lieut. Ekelund has done, and my own conviction is that we can collect this powder at less than 25 cents per ton if our bog were a large one and our automobile collector were completed.

As to our experience with firing with peat dust, our great difficulty was the grinding. We would wear off a set of plates in a day, and the dust and noise of operating the grinder were intolerable. It was a very efficient steam raiser, however; was simple to operate and did not injure the boilers. But as wood was plentiful and the drying and grinding so difficult, we gave up using it as a fuel two years ago. But if I was assured that some efficient means of grinding the peat could be had I would return to it again, as it was a cheap and efficient means of raising steam.

* Reproduced from the *Journal of the American Peat Society*.

Fire-proof Stove Varnish.—Black: Gilsonite or asphalt, copal and linseed oil, with the addition of some thickened wood oil, makes, according to *Technische Rundschau*, excellent stove varnish, the temperature and duration of burning-in increasing with the proportion of oil. For practical recipes, price and the temperature at which burning-in is to be effected are prescribed and this governs the composition. As a rule, compositions of gilsonite, stearine, pitch, Manila copal, hardened rosin and wood oil are used, for instance, 25 parts gilsonite, 3 parts stearine pitch, 3 parts Manila copal melted, 5 parts hardened rosin, 10 parts of wood oil (thick oil boiled with litharge and manganese), 5 parts pine tar, 10 parts of oil siccative. The composition is thinned to brushing or dripping consistency with sangajol, and is said to furnish a good stove varnish. Silver: 10 parts of melted Manila copal, 8 parts thick oil (from linseed oil), 3 parts aluminium bronze, addition of oil of turpentine until of painting consistency. White: Dammar and thick oil, thinned with benzine and zinc-white added. Stove temperature 60 deg. Cent. (140 deg. Fahr.).

Fig. 8.—No. 317B. Nail. Longitudinal, Showing Weld. Magnified 40 Diameters.

Fig. 9.—No. 317. Nail. Transverse. Magnified 40 Diameters.

Fig. 10.—No. 319. Billhook Transverse. Magnified 40 Diameters.

Sinhalese Iron and Steel of Ancient Origin—IV*

Beginnings of the Iron Age

By Sir Robert Hadfield, F.R.S., Sheffield

Concluded from Scientific American Supplement No. 1920, Page 253, October 19, 1912

VII.

DESCRIPTION OF THE RESEARCH EXPERIMENTS.

Details of the various specimens and an account of the research conducted, with the results achieved, may now be given, these experiments being carried out by the author at the Hecla Works Laboratory and Research Department.

Experiment No. 2252.—This was carried out upon the ancient Sinhalese chisel, being specimen marked No. 1 by Dr. Willey, and shown in Fig. 5. This dates back to the fifth century. The specimen was very rough, but without scale, and had an undulating surface, possibly due to unequal corrosion, and it is possible that the material was forged with rough implements of stone. The chisel was about 10 inches in length, and at the upper portion away from the edge about 1 3/16 inches square, 15/16 by 9/16 inch in the center, tapering to a point as with modern tools.

Table I.—*Composition.*

	Per cent.
Carbon	traces
Silicon	0.12
Sulphur	0.003
Phosphorus	0.28
Manganese	nil
Iron	99.3

The difference represents slag and oxide.
Specific gravity, 7.69.

Tensile Strength.—The Fremont shear test showed 16 tons per square inch elastic limit, 26 tons per square inch breaking load.

Shock Test.—The shock test, on unnicked specimen, showed 17 kilogrammes, with 85 degrees bend before breaking.

Hardness.—The Brinell ball test showed hardness numbers of 144 and 144 on the opposite side of the chisel.

The scleroscopic hardness number was 35.

The fracture was unsound, apparently owing to the existence of unsoundness or blow-holes. The crystalline structure showed large sparkling crystals. The micro-structure of the specimens (see Figs. 12 to 15, pages 260 and 261) brings out several points of interest. The transverse section shows that this chisel has been carburized, the section showing the carburized areas to be on two sides. The carbonization varies on the two faces from saturation point (0.9 per cent) to about 0.2 per cent carbon on the outside edge, and the depth of the carburization from the edge inward is also shown to be variable. The presence of martensite and hardenite, seen in Figs. 13 and 14, suggests the important information that the chisel has been quenched. Some of the crystals give evidence of a structure probably due to impurities of phosphorus and sulphur. The longitudinal photographs of both the chisel and the nail show this structure. Fig. 12 represents the transverse and Fig. 13 the longitudinal section of the chisel.

Further micro-sections were prepared from the specimen cut from the nose of the ancient chisel. These are shown by Figs. 14 and 15, page 260. Fig. 14 represents a longitudinal section from the chisel-point where worn down; and Fig. 15 in the main approximately shows the outside edges of the chisel, as indicated by the black lines. These outside edges are naturally somewhat out of focus. These photo-micrographs appear, in the author's view, to carry evidence that the chisel has been quenched, for the structure is in parts martensitic. Troostite is certainly also present, which is probably the result of tempering by the long lapse of time.

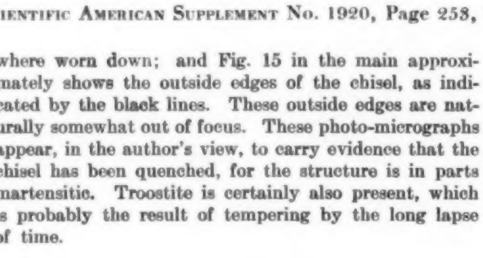


Fig. 14.—No. 389A. Chisel, from Point. Longitudinal Section. Magnified 40 Diameters.

The author believes this to be the first time there has been put on record evidence of the art of cementation having been known 1,500 to 2,000 years ago, as shown by these specimens; probably, therefore, such knowledge could be traced back still further.

Experiment No. 2253.—This was carried out upon the ancient Sinhalese nail, specimen marked No. 2 by Dr. Willey, as is shown in specimen Fig. 6, page 221. This is probably of the same origin and age as the chisel just described. This nail is about 13½ inches in length and 5/8 inch by 9/16 inch at the point; the extreme point is missing.

Tensile Strength.—The Fremont shear test showed 11 tons per square inch elastic limit, 21 tons per square inch breaking load.

Shock Test.—The shock test on unnicked specimen was 0.5 kilogramme by 1 degree—that is, it was very brittle.

Hardness.—The Brinell ball test showed hardness numbers of 117 and 209 on opposite side of the nail.

The scleroscope hardness was 44.

Table II.—*Composition.*

	Per cent.
Carbon	traces
Silicon	0.11
Sulphur	nil
Phosphorus	0.32
Manganese	nil

Specific gravity, 7.69.

The fracture revealed a fine bright crystalline structure.

The micro-structure, Figs. 8 and 9, indicates a remarkable conglomeration. Fig. 8 shows a weld running diagonally across the section, and along the edges of the weld there are carburized areas. Another notable point is that on one side of the weld the slag shows the effect of the forging, whereas on the other side there is no such sign. The specimen is covered with slip-bands, and has evidently undergone severe hammering, probably in its use as a nail. The carbon in the carburized areas exists as granular pearlite. Fig. 9 is a transverse section, and Fig. 8 a longitudinal section.

The longitudinal photographs of both the chisel and the nail, given in Figs. 8 and 13, show evidence of a structure.

The fragment from the nail was heated and forged well up to about 1150 deg. Cent. As forged, the Brinell ball hardness number was 120. The same material heated to 1050 deg. Cent. and quenched in water showed 130 Brinell ball hardness number, showing that it was not hardened by quenching.

Experiment No 2254.—This was carried out upon the ancient Sinhalese bill-hook, specimen marked No. 3 by Dr. Willey, and is shown in Fig. 7. The specimen was very corroded, being covered with a thick brown rust.

The bill-hook is about 12½ inches in length, 3 1/8 inches in width at the blade, the handle being 4½ inches in length.

Table III.—*Composition.*

	Per cent.
Carbon	traces
Silicon	0.26
Sulphur	0.022
Phosphorus	0.34
Manganese	traces

Specific gravity, 7.50.

Tensile Strength.—The Fremont shear test showed 16 tons per square inch elastic limit, with 29 tons per square inch breaking load.

Shock Test.—The shock test on unnicked specimen gave 7.1 kilogrammes by 35 degrees bend only.

Hardness.—The Brinell ball test showed hardness numbers of 153 and 166 on opposite sides of the bill-hook.

The scleroscope hardness gave number 23.

The fracture showed bright crystalline structure, laminated appearance.

The micro-structure of the specimen, as shown by Figs. 10 and 11, shows that it contains a large amount of slag, and appears to represent what would be now termed a somewhat low quality of wrought iron. There seems to be practically no carbon present, and therefore no evidence of treatment other than forging can

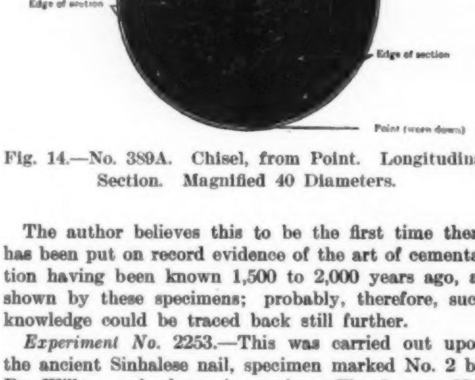


Fig. 15.—No. 389C. Chisel from Point. Longitudinal Section. Magnified 40 Diameters.

* Excerpts from a paper read before the Iron and Steel Institute, May 9th, 1912, and published in *Engineering.*

Fig. 11.—No. 319A. Billhook. Longitudinal. Magnified 40 Diameters.

Fig. 12.—No. 318. Chisel. Transverse. Magnified 40 Diameters.

Fig. 13.—No. 318A. Chisel. Longitudinal. Magnified 40 Diameters.

be obtained. Fig. 11 is the longitudinal section, and Fig. 10 the transverse section.

Special interest attaches to the analyses given, as they probably represent the only modern complete and accurate determination of the composition of known and authentic specimens of ancient iron.

The phosphorus is, it will be noted, high, from 0.28 per cent up to 0.34 per cent, which, however, does not greatly differ from modern bar-iron. The sulphur percentage is extremely low, showing that a very pure fuel—no doubt charcoal—was employed in the production of the material. There is very little silicon present, and manganese is entirely absent, which is somewhat remarkable, as nearly all iron contains some manganese. As the specimens were too small from which to produce tensile bars, these were obtained by means of the ingenious Fremont shear-test method. The tensile quality of the material averages about 26 tons per square inch, or a little higher than wrought iron. This, no doubt, is owing to the considerable percentage of phosphorus present, which stiffens or hardens iron. The Fremont shock tests show fair results on the specimen taken from the chisel—namely, 17 kilogrammes, with 85 degrees bend. The other specimens, however, show much lower figures—namely, the nail (1 kilogramme by only 1 degree bend), and the bill-hook (7 kilogrammes by 35 degrees bend). The hardness by the Brinell method varied from 117 to 166, one result from the nail showing 209; but this is abnormal, and cannot be accepted as representative. The scleroscope tests varied from 25 to 44, and as a comparison it may be mentioned that water-quenched carbon steel by this latter method shows 100, and ordinary wrought iron about 20.

From the microscopical examination and from the other tests carried out, the specimens represent a material of the type known as wrought iron, and not steel. The specimens somewhat resemble the material known as puddled iron, and appear to have been made from somewhat impure ore. The material is very low in its percentage of carbon, and, excepting phosphorus, also other impurities. There is present, in a lumpy, irregular form, quite a large amount of slag, indicating that the material has not been submitted to anything like the amount of squeezing and forging that modern wrought iron undergoes.

On etching the longitudinal micro-sections for tests for phosphides, the nail showed a clean weld of pure iron on the one side and impure wrought iron on the other. Whereas the former is free from phosphides, the latter etches quite black, with 10 per cent $CuCl_2$, showing presence of a large amount of phosphide of iron. The specimens from the chisel and bill-hook were also etched as macro tests.

CONCLUSION.

In concluding this paper, the author trusts that the facts set forth in this research add definite knowledge regarding ancient iron and steel. The production of such iron of satisfactory quality appears to have taken place on a large scale. The results set forth in this paper, and the various facts referred to regarding the production and use of iron in India, show that in ancient times metallurgical knowledge existed to quite a considerable degree.

This is not unnatural, seeing that Dr. V. Ball, M.A., F.G.S., in his admirable and exhaustive work on the "Geology of India," shows that the deposits of iron ore are very numerous in our Indian Empire. He adds his belief that "there are distinct evidences that Wootz was exported to the West in very early times, possibly 2,000 years ago." Without doubt, therefore, as the natives of India had in bygone ages ample sources of iron ore at their disposal, they knew how to produce iron and steel. It seems highly probable, therefore, that they did actually export their products to Egypt.

If, too, the photo-micrographs of the ancient Sinhalese chisel represent the current practice of that time, as probably was the case, the fact that the art of case-hardening or cementing and carburizing wrought iron—afterward quenched in order to produce articles with hardened cutting edges—was known, is an important piece of evidence, and proves that the art of iron and steel manufacture must at that time have been of quite a high order. In fact, combined with the information submitted regarding the remarkable wrought-iron pillars at Delhi and Dhār, the pillar at the latter place being at least 44 feet in length, and of considerable diameter, it would appear that even the production of masses which were not possible in Europe until quite recent times, were then undertaken. Beyond Nature's own productions of large meteoric masses, the author believes he is correct in stating that no such large masses were ever known to have been produced in the Western portion of our globe at this period. Eastern knowledge was, therefore, much superior to that of Europe.

It is important to know whether the facts stated in this paper warrant the conclusion, as they appear to do, that knowledge existed in ancient times with regard to hardening carburized iron. If they do, we should then have a satisfactory explanation of how the great works of stone, such as those seen in Egypt, were carried out in past ages—that is, probably by means of iron or steel tools, hardened and tempered to carry a cutting edge.

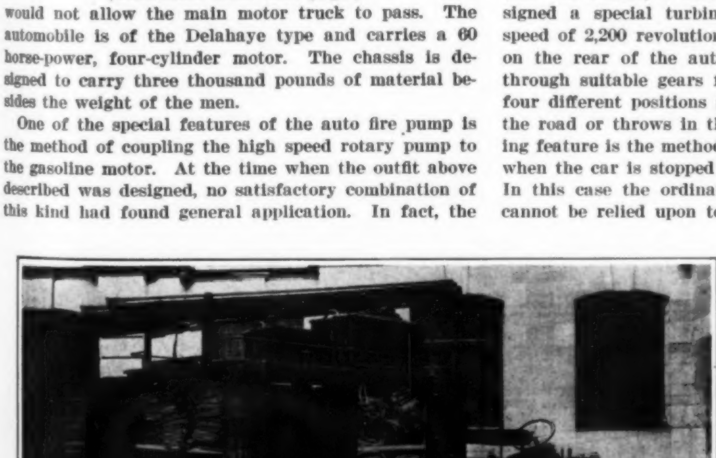
The Paris Fire Department—Its Latest Equipment

(Continued from first page.)

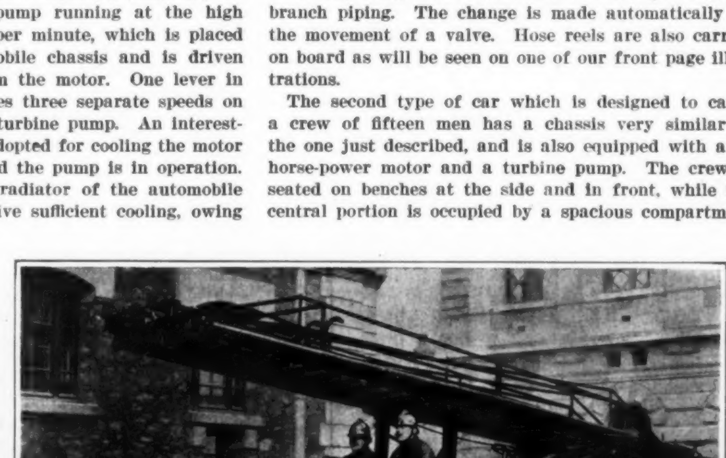
would not allow the main motor truck to pass. The automobile is of the Delahaye type and carries a 60 horse-power, four-cylinder motor. The chassis is designed to carry three thousand pounds of material besides the weight of the men.

One of the special features of the auto fire pump is the method of coupling the high speed rotary pump to the gasoline motor. At the time when the outfit above described was designed, no satisfactory combination of this kind had found general application. In fact, the use of the gasoline motor in conjunction with a piston pump of the usual kind presents considerable difficulties. M. Farcot, a well-known engineer, therefore, designed a special turbine pump running at the high speed of 2,200 revolutions per minute, which is placed on the rear of the automobile chassis and is driven through suitable gears from the motor. One lever in four different positions gives three separate speeds on the road or throws in the turbine pump. An interesting feature is the method adopted for cooling the motor when the car is stopped and the pump is in operation. In this case the ordinary radiator of the automobile cannot be relied upon to give sufficient cooling, owing to the lack of draft. But advantage is taken of the fact that the pump is delivering a steady stream of water, which is sent around the motor by a suitable branch piping. The change is made automatically by the movement of a valve. Hose reels are also carried on board as will be seen on one of our front page illustrations.

The second type of car which is designed to carry a crew of fifteen men has a chassis very similar to the one just described, and is also equipped with a 60 horse-power motor and a turbine pump. The crew is seated on benches at the side and in front, while the central portion is occupied by a spacious compartment



Salvage Car, a Feature Cordially Indorsed by the Fire Insurance Syndicate.



This Car Carries a Turbine Pump and a Portable Ladder Truck.

in which various appliances such as respirators, helmets, etc., are carried. On the two hose reels in front and the one in the back no less than twenty-five hundred feet of hose is carried. This is of two sizes, five-inch and one and one half inch. The total weight of the car is about seven tons. The rotary pump is sufficient to run three lines of hose with large nozzles or six lines with smaller nozzles.

Special interest attaches to the big ladder truck which serves as a base to support an extensible ladder capable of being run up eighty feet high. The ladder is supported in this position entirely on the automobile, which is held in position by placing rocks under the wheels. To manipulate the ladder, the car is brought up to the desired point and the springs are blocked so as to relieve them of the superincumbent weight. The several sections of the ladder are then drawn out by means of a 25 horse-power electric motor. The ladder itself is mounted upon a revolving base and also works upon a pivot, being counterbalanced so that it can be swung up and down to any desired angle by means of a crank. When extended to its full length of eighty feet, it can be set at an angle of 78 degrees, while sustaining a weight of five hundred pounds at the top. Even at an angle of 60 degrees it will still sustain the weight of a man at the end. When the ladder is to be telescoped the different sections are simply allowed to slide down by their own weight, the electric motor being run backward and thus acting as a brake. Lastly, there is a new salvage car, which should prove of great value in protecting property not only from fire, but also from being damaged by water. The body of this car contains tarpaulins, mops, brooms, sponges, bags of sawdust, etc. The crew of the car consists of eight men. The Fire Insurance Syndicate, in recognition of the value of this feature and to reduce damages to a minimum, has decided to allot the Salvage Department a substantial annual subsidy of 40,000 dollars.

Internal Combustion Engine Locomotives

Their Use and Possibilities

[The following comments from "An Engineering Correspondent" in the Engineering Supplement of the London Times deserves our careful attention.—EDITOR.]

THE statement that internal combustion engine locomotives are to be used on the Trans-Continental Railway of Australia brings prominently before the public the possibility of a new development in the use of the gas and oil engine. The main reason for its adoption in this instance is doubtless the lack of the necessary watering facilities for steam locomotives. It is possible to run an internal combustion engine all day without the consumption of any water, whereas a steam locomotive requires a constant supply. This useful feature of the internal combustion engine is accompanied by a very substantial economy in fuel. For instance, an average steam locomotive may be expected to burn some 4 pounds of coal per hour per horse-power, against about 1 pound of oil fuel for the same work on the part of an average oil engine. Thus, there is a saving not only in fuel costs, but also in handling charges, and, in addition, the disadvantages accompanying the production of smoke and cinders are avoided.

On the other hand, the steam engine is at present the simpler engine of the two, and is less liable to get out of order. Its advocates claim many advantages for it, such as lowness of initial cost, simplicity of the mechanism, ease of control and of reversal, steadiness of tractive effort, and smallness of depreciation and repair costs. The advocates of the internal combustion engine are equally energetic in claiming that their engine is extremely economical in fuel, that it requires little or no water, that with a suitable starting and transmission gear it is quite simple to control, and that it has the smoothest possible tractive effort, with a high starting acceleration.

The necessity of providing a special starting and transmission mechanism arises from the relatively poor flexibility of the oil engine. An oil engine will run excellently from say 1,000 down to 100 to 200 revolutions per minute, but is liable to stop altogether if run at a lower speed; this means that it cannot be in permanent connection with the driving wheels of its locomotive, else it would not start. To remedy this defect special mechanism, of a mechanical or other nature, is needed. In steam locomotives this direct connection is feasible, and it certainly affords the simplest arrangement. The reason why slow speeds are not possible with oil engines is that the explosive thrust on the connecting-rod is too intermittent to carry the engine round during the intervals between the pulses unless the speed is fast enough for it to be assisted across these intervals by its own momentum. Moreover, the temperature in the gases in an internal combustion engine is very high, and a slow speed gives a longer time for cooling and for consequent loss of explosive force. The use of an auxiliary device for transmitting the power to the wheels enables all these difficulties to be avoided, and it sometimes has the advantage of introducing other improvements, partly or wholly compensating for the additional complication involved.

SUPERHEATED STEAM.

Steam locomotives are built up to about 2,000 horse-power in capacity. It is now becoming usual in such cases to superheat the steam in order to get the greatest possible power out of the limited size of boiler prescribed by the loading gage in this country. The advantage which superheating brings is to permit the steam to drop in temperature, when entering the relatively cold cylinders, without condensation and consequent loss. Thus, more work is obtained for a given water consumption. Superheating converts the "steam" engine into a "gas" engine, since all vapors become gases when raised sufficiently in temperature above their "saturation temperature." This being so, the superheated steam engine may be termed a "gas" engine, though not, of course, an "internal combustion engine," since the flame is in the boiler firebox and not in the cylinder itself. Thus the question is raised why, if the most efficient form of present-day steam locomotives is in truth a "gas" engine, it can be of advantage to replace it with an oil engine, which equally is a "gas" engine. The argument seems pertinent, but it omits the important qualification that in the oil engine the whole of the energy of the fuel enters the cylinder, whereas in a steam engine a large proportion of the energy in the fuel is wasted before it reaches the cylinder. Moreover, unless the steam locomotive is fitted with a condenser, the latent heat of the steam is lost in the clouds escaping from the chimney. For these and other reasons the steam engine uses far more fuel per horse-power than the internal combustion engine.

ELECTRIC TRANSMISSION.

When the traffic requirements are such as to call for a speed and weight of train greater than can be provided by the 2,000 horse-power of the steam locomotive an alternative is required for meeting the situation. The electric solution is well known; the generating station can direct immense quantities of power to just those points on the railway where they are needed at any moment. It therefore affords a far more rapid train acceleration (up to 4 feet per second per second) than is possible with steam trains (which rarely exceed 1 foot per second per second). An advantage which this solution has over steam is the ability to distribute the driving power throughout the length of the train. If necessary every axle can be a driving axle, whereas in a steam train the whole of the tractive effort must come from the driving wheels of the locomotive, which, therefore, has to be made very heavy in order to provide sufficient adhesive weight, and this heaviness reacts in requiring a specially heavy rail, etc. If an oil engine be fitted the whole of the power may be directly transmitted to the engine wheels, as in the Diesel locomotive, or it may be transmitted electrically to as many axles as desired, as in the Thomas system or the Macfarlane-Burge system, or even hydraulically, as in the Hele-Shaw method. If it be transmitted electrically to a number of the carriage axles the tractive adhesion is correspondingly great, and high acceleration can be attained. This splitting up of the driving power may be carried to the length of having independently operated coaches, fitted with oil or gasoline engines; many railways have such coaches in use. It is possible that this is the best way of using the internal combustion engine for tractive effort on railways, and that the concentration of power in one engine will only be used for purposes for which it has special advantages.

DIESEL OIL LOCOMOTIVE.

Much attention has lately been paid to the possibilities of the Diesel oil engine. So far it has not been used for locomotive purposes on road or rail, but, as was announced a few weeks ago, Dr. Diesel is at work with Messrs. Sulzer Brothers, at Winterthur, and Herr Adolph Klose, of Berlin, on a 1,000 to 1,200 horse-power Diesel locomotive. Steam locomotives have, of course, been made of much larger sizes, and the above engine will not, therefore, improve on its immediate predecessors in this respect, but it may be expected to show very large economies in fuel consumption. The Diesel engine proposed for this work is of the two-stroke cycle, four-cylinder type, having its cylinders arranged in pairs at an angle of 90 degrees. The engine is directly geared to the driving wheels, and does not transform its power electrically. An auxiliary engine drives air pumps for giving increased torque when starting or when climbing a grade. The whole is expected to weigh about 85 tons. It will be seen that this locomotive gives the most direct form of challenge to the steam locomotive.

INDEPENDENT UNITS.

So long ago as 1906 the Missouri and Kansas Interurban Railway had a gasoline-driven railway car running some 220 miles a day on a scheduled service between Kansas City and Olathe; it is stated to have hauled two trailers with seating capacity for 225 persons. This engine coach, which weighed 39 tons, had a six-cylinder gasoline engine driving a dynamo, the current from which was led to electric motors. As the voltage was about 240 and the current 165 amperes, the power taken by the motors was some 40 kilowatts. Of course, an engine no larger than this would not be capable of giving great car speed; the speed in miles per hour on the level for all forms of vehicle being given by (375×horse-power)÷(R×W), where W is wheel weight in tons and R the total resistance in pounds per ton due to track and air.

Speeds up to 50 miles an hour are, however, quite feasible, and a high speed car has lately been supplied by the Leyland Company for use on the South African Railways. This car has an engine capable of yielding up to 200 horse-power, and it has a method of connecting and using the electric current due to Mr. Thomas, of the Thomas Transmission Company. The advantage gained in having an electric transmission between the engine and the driving wheels is that the whole of the output of the engine is available at starting and during hill climbing (instead of an output smaller than the full amount in proportion to the lower rate of engine revolutions). It is of no advantage, however, when running at full speed on the level, and in the Thomas system the engine then drives direct through to the road wheels. The electric gear is used only at the moments when it is needed, viz., when starting and when hill climbing. Two motors are fitted, and are connected to each other and to the engine by an epicyclic gearing which gives the engine great "mechanical advantage" when high torque is needed, and which automatically withdraws itself from action when the normal engine torque is sufficient. Another gasoline-electric system in some ways similar is the Macfarlane-Burge system recently discussed at a meeting of the Institution of Electrical Engineers. Here the engine is only a little larger than is necessary to give the power needed for running on the level. The extra power needed for hill climbing is drawn from a small storage battery charged by the surplus power from the engine and by downhill running (the braking is entirely electrical and is regenerative, which makes the design specially suitable for suburban traffic). The ingenious part of this system is the "electric valve," which, while limiting the possible current that can be drawn, has also the effect of giving a nearly constant value to the product of torque and speed; it acts, therefore, like a gear box with an infinite number of gear ratios. On the Great Central Railway there has lately been put into service a Westinghouse internal combustion engine coach having a 90 horse-power six-cylinder gasoline engine driving a 55-kilowatt dynamo, which, in turn, supplies power to two electric motors. This vehicle is stated to be capable of 40 miles an hour on the level, to weigh 25 tons, and to have seating capacity for 50 passengers.

The independently-operated motor coach, with or without its trailer, has been found to reduce very greatly the dead weight that has to be carried per passenger. This must in itself make very materially for economy in operation. The power required for propulsion per ton of dead load doubtless tends to be a little higher than in a long steam train, because the air resistance is greater when the cross section is large in proportion to total length, but, with suitable windcutting fronts and ends, there is no reason why this effect should not be minimized. It is desirable that both ends of the coach should be shaped to give low air resistance, not only because such coaches are driven equally well from either end, but because experiment has shown that it is just as important to close up gradually the air streamlines behind as to open them out smoothly in the front.

Many railways at home and abroad are now taking an active interest in this matter, and there is little doubt that a wide field of usefulness lies before this application of the internal combustion engine.

Recent Progress in Illumination*

Report of a Committee Appointed by the Illuminating Engineering Society

The past year has been one of gradual and rather satisfactory progress in the science and art of illumination. No radical novelties in apparatus have forced their way to the front nor has there been any startling innovation in methods, but it is gratifying to note that more attention than ever before has been paid to the proper installation of lamps and the public has awakened to a fuller realization of the necessity of scientific methods in illumination.

PROGRESS IN GAS LIGHTING.

The most conspicuous advance in the material of gas lighting during the past year has been the extensive introduction of the artificial silk mantle. This material has shown itself capable of longer life and more uniform efficiency than anything yet tried as a material for mantles. A few inverted mantles of this type have been in use for some little time past. This year at last they have been pushed into extensive use and the upright mantles of artificial silk, previously not available in this country, have now been placed upon the market. The inverted mantle has been of late rapidly replacing the older upright mantle on account of its better distribution for most purposes and its better qualities in other respects. This year, however, the increase of interest in indirect illumination has again brought the upright mantle to the front as having a more favorable distribution for indirect lighting than the inverted mantle.

The use of high pressure lighting has increased conspicuously abroad, but as yet few and small permanent installations have been made in this country. The interest in the subject has been awakened, however, and the number of experimental installations has been considerably increased. Appliances of high pressure lighting have been materially improved so that there is good reason for paying more attention to this particular phase of gas lighting.

Among comparatively new uses of gas lighting, due to the availability of better and more powerful burners, can be mentioned the use of incandescent gas lamps by photographers, a comparatively recent innovation which has met with considerable success.

The general efficiency of the mantle burners in commercial use has been the subject of improvement and what is of greater interest to the public the manufacturers have met the demand for a wider range of burner sizes; so that there are now on the market burners, of both the inverted and the upright types, of many different powers, consuming from as little as 1 cubic foot of gas per hour up to 7 cubic feet.

It should be noted that improvement in gas fixtures during the past year has been somewhat noticeable, and particularly to be commended is the adoption of a standard specification calling for gas fixtures of better and more uniform quality. Such a specification is now in the course of preparation by representatives of gas companies and fixture manufacturers; it is expected that it will be generally adopted and produce a salutary effect on the quality of these installations.

ELECTRIC INCANDESCENT LAMPS AND LIGHTING.

The most important change of the past year in incandescent lighting has been the very widespread adoption of the drawn wire tungsten filament. Tungsten wire can now be drawn of much smaller diameter than has previously been available; so that commercial tungsten lamps of as low as 10 watts have been produced, which can operate successfully on a 110-volt circuit. The 15 or 16-watt size, however, is the smallest tungsten lamp in any considerable use as yet. The smaller tungsten units are already in growing use abroad and bid fair to become an important factor in certain classes of lighting. The larger tungsten lamps up to 500 watts have within the last year awakened a considerably increased demand in competition with both gas and electric arcs. On the Continent tungsten lamps up to even 1,000 watts are coming into commercial use, but the largest of these sizes are still unusual.

The tungsten lamp as now used in this country remains at the same nominal efficiency as heretofore, but it must be noted that on the Continent 8/10 watt per candle is a specific consumption now very frequently quoted. This is based on the Hefner unit and is therefore nearly 9/10 watt per candle when based on the international candle. At this figure an economical life of 500 hours or more has been repeatedly claimed. It is naturally to be expected, therefore, that the lamps of manufacturers in this country are likely to be rated at a higher efficiency than now, since there is no reason to suppose that the American product is in any way inferior to foreign lamps.

We are glad to be able to report that there is some chance of a reduction in the size of the bulbs of tungsten lamps, possibly at slightly increased trouble from blackening, but in view of possible better performance of the filament still leaving a residual advantage to the user.

The metallized filament carbon lamp has found its place for usefulness in the rapid replacement of ordinary carbon lamps for nearly all purposes. It is now available in all the shapes and sizes once familiar in the latter with equally good life and materially higher efficiency.

ARC LAMPS.

In this country the chief direction of advance in arc lamps has been toward the production of long burning flame lamps which have been adopted on a considerable scale in Chicago and at some other points. A fairly economical lamp of this type with an electrode life of 100 hours or more has been produced by several manufacturers and gives good promise of usefulness where units of high power are necessary. There is, of course, danger that attempts to increase the electrode life may entail serious loss in efficiency, but the present indications are that the improvement in the quality of the electrodes has in a considerable measure met this difficulty. The tendency is to use electrodes mineralized practically throughout, instead of simply in a core of modest dimensions carrying enough light-giving material to compensate in part for the longer time of burning per inch of electrode. The same tendency is active abroad and goes far to eliminate competition from the larger tungsten lamps by reducing cost of operation of the arc lamps.

A three-phase lamp with three converging carbons has been introduced abroad; it furnishes a very powerful light of remarkable low specific consumption and is adaptable for circuits of frequency as low as 25 cycles per second. In this country the principal novelty is the so-called "Boulevard" type of magnetite arc lamp which furnishes for spectacular illumination a unit of great power and efficiency extremely well suited to decorative purposes. This lamp is now used in a number of cities with admirable results.

The titanium carbide arc in an improved form has been introduced for use on alternating current circuits, and gives new promise of general usefulness.

Finally, intensified carbon arc lamps, which have been pushed to a point of high efficiency, have been steadily coming into increasing use, well merited on account of their great regularity in performance and the admirable quality of their light where color discrimination is necessary. They are tending rapidly to replace the earlier forms of enclosed arc lamps which are now happily becoming obsolescent.

NEW TYPES OF ILLUMINANT.

The production of an artificial light capable of fully replacing daylight for color matching purposes has been a subject conspicuously to the fore during the past year. One type of intensified arc with a carefully adjusted glass screen of a highly ingenious character has come into use with good results. Two similar forms based on tungsten lamps with colored screens have also appeared. All three seem to produce pretty satisfactory results at, of course, a very much reduced efficiency. The use of the Moore carbon dioxid tube for the same purpose has increased. In this category might also be placed the mercury-vapor lamp with the rhodamine reflector. No device for obtaining daylight values of illumination sufficient to meet all the requirements of color discrimination has as yet been entirely satisfactory, all of those yet devised being open to criticism on theoretical considerations, though all are undoubtedly capable of great usefulness in meeting the trying conditions of this problem. It is fair to say that they do not vary among themselves more than the different conceptions of "white light" vary. It would be exceedingly interesting to see what could be done with mantle gas burners properly screened in meeting this requirement. A daylight unit of this character is now being developed with promising results.

The most interesting of new illuminants from the theoretical standpoint is undoubtedly the neon vacuum tube lamp, developed in France, to which brief reference was made in the report of the committee on progress last year. Further details of its performance are now available. The rare gas neon, which forms a minor constituent of the atmosphere, can now be obtained in commercial quantities as a by-product of the preparation of liquid oxygen from air. The Paris works engaged in this industry even now can produce enough neon daily to fill 1,000 tubes of 1,000 candle-power each if so many should be required. The ordinary tubes are of about 6 meters in length and give about 900 spherical candle-power. The power factor is about 0.8 and its specific consumption is 0.72 watt per mean spherical candle-power at the terminals or about 0.9 watt including transformer and inductive losses. The color of the light is extraordinary, being a beautiful orange, entirely lacking blue rays, just as the ordinary mercury-vapor arc lacks red rays. No progress has yet been made toward the introduction of this interesting light into this country.

Finally, the quartz mercury arc lamps have made large progress within the past year. These lamps are not lacking in red rays as is the ordinary form of mercury-vapor arc, but are still subnormal in the red. It would be extremely interesting to know the result of operating them with the rhodamine reflector for a white light.

RESULTS OF TECHNICAL RESEARCH.

A considerable amount of work along physiological lines has been done during the past year both here and abroad. One of the results has been the suppression of the ultra-violet bugaboo by making it clear that under the condition of practical illumination, natural or artificial, there is substantially nothing to be feared from ultra-violet radiation, in which the light of the sky and that of several important commercial illuminants is somewhat rich.

Another line of investigation directed toward the value of diffusion in illumination has furnished added evidence of its importance, not only in lowering the intrinsic brilliancy of all feasible sources, but also in reducing the reflected glare that is so serious an obstacle to vision.

Still another important addition to our knowledge lies in some of the photometric researches of the past year. Several of these have been directed toward the solution of some of the problems of heterochromatic photometry with the general result of strengthening the position of the flicker photometer for such purposes, and incidentally of showing the limitations of the more ordinary photometric methods and the devices by which they can be successfully applied to heterochromatic problems of the character usually arising in commercial photometry.

Important studies have also been made of the solution of photometric difficulties by methods eliminating the idiosyncracies of the eye through the use of selenium or other light sensitive cells. It has been shown, for instance, that for the selenium cell Talbot's law holds; and that within the bright part of the spectrum one can depend on a definite relation between the constants of the cell and the illumination, provided the latter be within determined limits. Curiously enough it is found that the constants of the cell vary so as to produce a species of Purkinje phenomena, the maximum sensitiveness lying in the yellow green at very low illuminations and in the red at very high illuminations.

There has also been a most ingenious attempt at producing a primary standard of light from incandescent platinium at the hands of two English investigators. A strip of platinium is electrically heated and held at a determinate temperature by the effect of the physical radiation filtered out through a water cell and a black fluorspar screen on a thermopile which indicates the radiant energy. The device was found to be good for a constancy within plus or minus ½ per cent, but whether it will prove any more workable in practise than various forms of the Violle standard remains to be seen.

NEW AUXILIARIES AND SOURCES OF BUSINESS.

The line of reflectors of various sorts available for the illuminating engineer has been largely increased during the past year. The most notable change has been in the direction of indirect and semi-indirect lighting; the latter particularly has found numerous applications and the line of suitable glassware has been largely increased so that at the present time it is possible to obtain both indirect and semi-indirect lighting fixtures which are not only efficient but even decorative. As regards other shades and reflectors the principal changes have been in the direction of the improvement of metallic reflectors and their greater adaptation to meeting the requirements of the art of illumination, and in the production of well designed glassware of an ornamental character. The stigma placed upon the illuminating engineer that he has persisted in recommending hideous shades and reflectors bids fair to be permanently removed.

As regards increasing opportunities for use of light there has been a tremendous growth of so-called "great white way" lighting, generally carried out as the result of the private enterprise of boards of trade or groups of merchants. Some of it is admirable from the standpoint of illumination; all of it ought to be. Unquestionably, its effect will be greatly to increase the amount of street lighting whether it is permanently done at private expense or not. Illuminating engineers should use their best efforts when dealing with this class of work to make it so good from the standpoint of efficiency and artistic effect as to make it a permanent and growing branch of outside illumination.

* Transactions of the Illuminating Engineers' Society, September 16th to 19th, 1912, Niagara Falls, Ont.

Fig. 1.—Interior of the 60,000 Horse-power Electric Station Utilizing Blast Furnace Gas.

A Sixty Thousand H -Po Gas E e P

Electrical Generating Units and Blas rnace a

By C. Tupper

The largest gas engine driven power plant in Europe, and the one which impressed the writer the most favorably of any visited, is that of the Gewerkschaft Deutscher Kaiser at Bruckhausen, on the Rhine, in Germany, which has a present capacity of 60,000 horse-power. It supplies current for operating coal mines, coke ovens and a by-products plant, blast furnaces, open-hearth, converter and electric steel plants, roughing and finishing mills and fabricating plants, foundries, machine shops, etc., and also for transmission over an independent electric system serving the communities and industries of an extensive district.

The power house has a length of 459 feet and a width approximating 252 feet, being divided longitudinally into three parts, viz,: electric plant, 110 feet; blowing engine house, 116 feet, and a central bay, open at the bottom along each of the two 459 feet sides, which contains auxiliary machinery, offices and various conveniences. This takes up the remaining 26 feet of width. The power-house building is of steel frame construction with the roof and the sides very largely composed of glass, which affords excellent natural lighting throughout. At night the plant is illuminated by arc lamps and pillar clusters of incandescent lights. The floor is of tile, covered in the main passages and aisles with rubber matting.

The electric plant, from an interior view of which Fig. 1 has been taken, contains 12 units. All of the engines are four-cycle double-acting machines, 9 tandem and 3 twin-tandem, built by the Maschinenfabrik Thyssen & Co., Mülheim-Ruhr, Germany. Of the first named, four have cylinders 43.3 inches in diameter, by 51.3 inches stroke, and to each engine a 1,450 kilowatt generator is direct connected; five have cylinders 48 inches in diameter by 55 inches stroke, and drive 2,000 kilowatt generators direct coupled, and the three largest have 51 inches cylinders by 59 inches stroke. To each of these a 4,500 kilowatt generator is direct connected.

All of the gas used in the engines is that generated by the blast furnaces, from the tops of which it is taken in the usual manner. After passing through 22 feet dry dust catchers, the gas is collected in two gas mains, 8 feet 6 inches in diameter, with a third held in reserve, which discharge to the 13-foot header of the cleaning plant proper. Here the first receptacles are three dry dust catchers, 19 feet 8 inches in diameter by 25 feet high, elevated sufficiently above the yard level to enable the accumulated dust to be dumped into dustproof inclosed railroad cars of a special design, in which the dust is transported to a briquetting plant. Each dust catcher can be shut off by means of a valve of the water sealed, mushroom type, and is connected to two wet scrubbers arranged in series. The six wet scrubbers are arranged in rows of three, those of each row operating in parallel while the two rows work in series. These scrubbers the towers of which are 24 feet in diameter by 32 feet high, are of the Zschocke type designed and built by the Zschocke Werke, Kaiserlautern, Germany.

* The Iron Age.

After leaving the scrubbers the dry cleaned gas is collected in one large main of 13 feet diameter, which distributes it to six hydraulic fans of the Schiele type. The branch pipes to each fan are 4 feet 3 inches in diameter. The outlet pipes discharge the clean gas into water separators and thence into another collecting main 12 feet 6 inches in diameter, whence it returns to the blast furnace stoves in two 8-foot pipes, which form a complete loop around the furnace plant. Water sealed mushroom valves, conveniently arranged, permit the shutting off of any section of this ring main when required for cleaning purposes.

From this collecting main the gas available for the power plant is drawn off in a 6-foot 6-inch pipe and carried to the secondary cleaning plant. The latter consists of five Schiele fans discharging the fine gas into water separators and thence into the final collecting main, which is connected to a gas holder 60 feet in diameter and of about 175,000 cubic feet capacity. Another branch of 5 feet diameter by-passes the gas holder, giving direct connection to the power plant when the holder is not in service.

The raw gas contains, on an average, 3.5 grains of dust per cubic foot. It leaves the Zschocke scrubbers with a content of about 0.50 grain per cubic foot, which drops to about 0.11 grain per cubic foot after the preliminary Schiele cleaning fans. In the secondary cleaning plant the amount of the dust is reduced to about 0.013 grain per cubic foot, the gas arriving at the engines with a content of about 0.011 grain per cubic foot (about 0.025 grammes per cubic meter). The dust determinator is of the Stroehlein cotton-method type.

The temperature of the gas entering the cleaning plant (carried in unlined pipes across the ore yard for about 1,200 feet) is 194 to 212 deg. Fahr. This temperature is reduced to about 79 deg. Fahr. behind the Zschocke washers and is about 70.5 degrees after the Schiele fans. The temperature of the water supply is 79 degrees and the waste leaves the washers at 104 degrees. The quantity of water consumed for cleaning is 30 gallons per 1,000 cubic feet for the preliminary processes, in which quantity the Zschocke scrubbers share with 23 and the Zschocke fans with 7 gallons. The quantity of water used in the secondary plant, having the Schiele fans, is 12 gallons per 1,000 cubic feet, so that a total of about 42 gallons per cubic feet is required.

This quantity of water, which will, of course, vary somewhat either way according to conditions, is remarkably small; but, due to the scarcity of the supply, the management has adopted every possible means of conserving it. All of the waste water from the gas cleaning plant is carefully collected and carried in launders to two settling tanks for purification. One of these, which has nine compartments with a total area of 80,000 square feet, takes the water from the wet scrubbers only, while the waste from the preliminary and secondary fans is purified in the smaller tank of four compartments and 27,000 square feet area. The waste water passes through the compartments of the tanks in series and thence flows to a reservoir to be pumped over a cooling tower 150×45 feet in area, with natural draft. For this purpose there are three centrifugal pumps, and the cooled water is raised by another set to the top of a distributing tower. The residue from the cleaning tanks is removed by means of grab buckets operated from gantry cranes and conveyed to the coal mines on the property for use in back-filling.

The gas enters the power plant through a ring main 6 feet 6 inches in diameter, from which feeder pipes of 20 inches diameter branch off to the engines. This piping is laid underneath the floor and is readily accessible. The combustion air for the engine cylinders is taken in through ducts which are integral with the concrete foundations and terminate on the outside in pockets protected by wire gauze. The piping for the cooling water, compressed air used in starting, etc., is laid similarly to that for gas. All of the conduits and the pipes, which are painted different colors to indicate their purpose, have been arranged on the loop system, to enable the engines to be supplied from either direction, and any unit may be cut off from the mains common to all without interrupting the service of the others.

Immediately adjacent to each engine there is a gas receiver, with supply pipes leading to each cylinder. The gas supply reaches the engine from the receiver through the left-hand pipe in Fig. 4, and a handhole is provided in the port leading to the gas valves, through which any deposit can be removed as required. The gas supply to each end of each cylinder can be independently adjusted by means of the hand wheels shown on the side of the right-hand cylinder in Fig. 3, which actuates a link motion for opening or closing the valves shown immediately above the cylinder in Fig. 4.

The air-supply pipe is the larger pipe at the left in Fig. 4, and a valve is provided by means of which the proportion of air drawn in can be regulated by hand. Having these two adjustments, the engine can be run on gas of any quality suitable for power purposes, since, by varying the realative degrees of opening and closing of these valves on the air and gas supplies, the proportion of air to gas can be varied through as wide a range as needed. Closer regulation, to meet all operating conditions, is obtained through the additional throttle valves shown above the left-hand cylinder in Fig. 3, which are under the direct control of the governor.

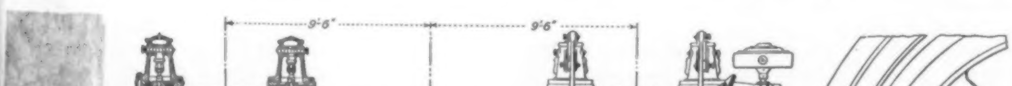


Fig. 3.—Section Through Cylinders of Thyssen Gas Engine.

d H -Power Blast Furnace s En e Plant*

nd Blas nace and Converter Blowing Engines

By C. Tupper

Fig. 2.—View of Gas-driven Blowing Engines, Bruckhausen, Germany.

Particular attention is directed to the arrangement for admitting gas and air to the engine cylinder. As will be observed from Fig. 3, the gas valve is on the same spindle as the main inlet valve, and there is also a sleeve on this spindle which, when the valve is seated, covers the air port. Thus the opening to air is always proportional to the opening for gas. These inlet valves are operated by an eccentric on the side shaft and have a constant opening, the governing being effected not by varying the lift or duration of opening of this valve but by means of the throttle valves.

The exhaust valves, it will be seen, are located below the cylinder and are wholly contained in separately cast boxes, which can be readily removed when the valves require examination or any work is to be done on them. The engine exhaust, as shown in Fig. 4, is through suitable piping to concrete muffler tunnels on either side of the plant, connected to the atmosphere through steel stacks.

The jacket is cast integral with the cylinder, but it is fitted with a renewable liner which takes all the wear. Both cylinder heads and pistons are water cooled, as shown in Fig. 3, and the water cooling of the exhaust valves and their casings has been amply provided for. The cooling water enters at about 72 to 78 deg. Fahr. and leaves at 104 to 108 deg. Fahr., flowing into a reservoir. From this it is pumped to a cooling tower equipped with fans, where the temperature is reduced to about 75 degrees. Approximately 12 gallons of water, on the average, is needed per brake horse-power hour.

For the cylinders there is forced lubrication, oil being pumped in through a pipe piercing the water jacket, extending diagonally to the top of the cylinder in Fig. 4. As the engines are four-cycle machines, the side shaft has to be geared down. This is effected by spiral gearing located between the flywheel and one of the main bearings, and the gearing runs in an oil bath, being fully inclosed. The crank shaft has three bearings, that on the right hand having a spherical seat. The brasses are lined with white metal, and the lubrication here is also forced. There is no central oil supply, but each engine has been provided with its own system throughout. As the oil is used it flows to a tank in the basement under each engine and is pumped back through a strainer. This keeps it clean enough so that filtering has to be done only once in two or three months.

The two cylinders in tandem are connected at the top by steel stays supplementing the tie piece. Similar stays lead from the first cylinder to the top of the main bearings, and this tends to relieve the engine frame from the bending strains which were so frequent a source of trouble in earlier days. The two piston rods are connected by a cross head and the tailrod at the rear is suitably guided. Hence the pistons and the rods float in the cylinders, and their weight is taken off the glands. The gland packings are metallic.

The generators direct coupled to the gas engines are alternating current machines of the usual revolving field type, supplying three-phase, 50-cycle current at a terminal pressure of 5,000 volts. Each is built with a heavy flywheel rotor, except for the three first installed, which have separate flywheels. The earlier machines were from the Siemens-Schuckert Werke, while the latest have been constructed by the Allgemeine Elektricitäts Gesellschaft, Berlin. When the production is greater than the local needs the excess current can be turned into the great independent system of the Rheinische-Westphalische Elektricitäts Werke, which has a network of transmission lines connecting districts in a great part of the coal, iron and steel producing section of north Germany. The sale of current for this purpose is a good source of income for the Gewerkschaft Deutscher Kaiser, although its own consumption has averaged of late about 70 per cent of the maximum capacity of the herein described plant.

From the electric plant the visitor to the power-house passes into the longitudinal central compartment, or bay, 26 feet wide, which has its main floor depressed below the level of the generator and blower rooms. On this are installed the pumps, air compressors and tanks, exciter units, transformers, etc., as well as an oil filter plant; while on the floor above are offices, a dining-room, lockers, toilet-rooms, etc., and a storage battery installation for supplying the incandescent lights, thus preventing the station from being plunged into darkness should the main lighting system fail. The battery for ignition current is also located here. Leading down to the floor of the bay from the electric and blower plants are stairways placed opposite the engine units, affording means of quick communication between the several departments.

The blowing engine plant of the Gewerkschaft Deutscher Kaiser extends the full length of the 489-foot power-house and occupies 116 feet of the width, being separated from the electric plant only by the central bay. The arrangement of this is, in general, similar to that of the generator room, already described, the layout of the gas, combustion-air and starting-air piping, cooling system, lubrication, etc., being the same. There are seven blowing engines for supplying blast furnaces, one being always held in reserve. Four of these units have gas cylinders and blowing tubs 43.3 inches and 100.8 inches in diameter, respectively, with 51.2-inch stroke, and are capable of delivering about 40,000 cubic feet of free air per minute at the maximum rated speed of 90 revolutions per minute; while three units have cylinders and tubs 48 and 114.3 inches in diameter by 55.1-inch stroke, with a displacement of 56,000 cubic feet of free air per minute at the same speed. The usual working speed limit is, however, 80 revolutions per minute, with corresponding capacity. The normal operating pressure of the units is 10.3 pounds above atmosphere; but each is so designed as to enable it to deliver air at higher pressures up to 14.7 pounds or beyond, with corresponding reduction in volume. All were built by the Maschinenfabrik Thyssen & Co.

Each of the furnace blowers discharges into an air dome, manufactured by the engine builders, which is 40 feet long and 10 feet in diameter, made of 5⅝-inch steel with welded seams. This effectually prevents any leakage of air or oil and serves as a pressure equalizer, eliminating vibrations in the cold blast piping and elsewhere. The blast pipe leading to each of the six furnaces is 4 feet in diameter, with accordion expansion joints, and the system is arranged so that any engine may supply the blast for any furnace. In practice two engines are usually blowing one furnace.

There is also in the blower department two Thyssen twin-tandem blowers for converter service, which have cylinders and tubs 48 inches and 74.8 inches in diameter by 55.1-inch stroke. Each also operates at 90 revolutions per minute and has a maximum capacity of about 50,000 cubic feet at 36 pounds pressure and can also blow to 44 pounds. These blowing engines are stated to be the largest of the type thus far built. The second unit had not been erected when the writer was in Bruckhausen, but the first had given entire satisfaction. Particularly remarked upon by the engineer in charge were the accessibility of all parts and the ease of regulation, all of which is effected from one position. The machines have no governors, but each is operated from the stand between the cylinders, where the main gas throttle valve, the hand wheels for mixing adjustment and ignition timing, as well as the hydraulic unloading levers, are conveniently located, so that one man can handle the engine.

During so-called blowing up periods of the converters a valve in the blast main is open, while another valve in a branch pipe to the atmosphere is closed. During the blowing down periods the engine continues at full speed and the air is blown into the atmosphere by reversing the hydraulic valves. It is, of course, peculiar to the operation of converters that greater demands must be made upon the quick regulation of the air pressure and volumetric delivery of a blower for this service than upon one discharging to blast furnaces. When the first of the two machines just described was under consideration it was argued that steam-driven blowers would be more reliable, or that, if gas-driven blowers were chosen, the two-cycle engine would be better adapted to the service than the four-cycle, particularly at low speeds. It has proved, however, that the four-cycle machines installed at Bruckhausen, as well as similar converter blowing engines from the Maschinenfabrik Thyssen & Co., have fulfilled all of the demands made upon them. In addition to the unloading device at the blower end, by means of which the air volume from full load to no load can be

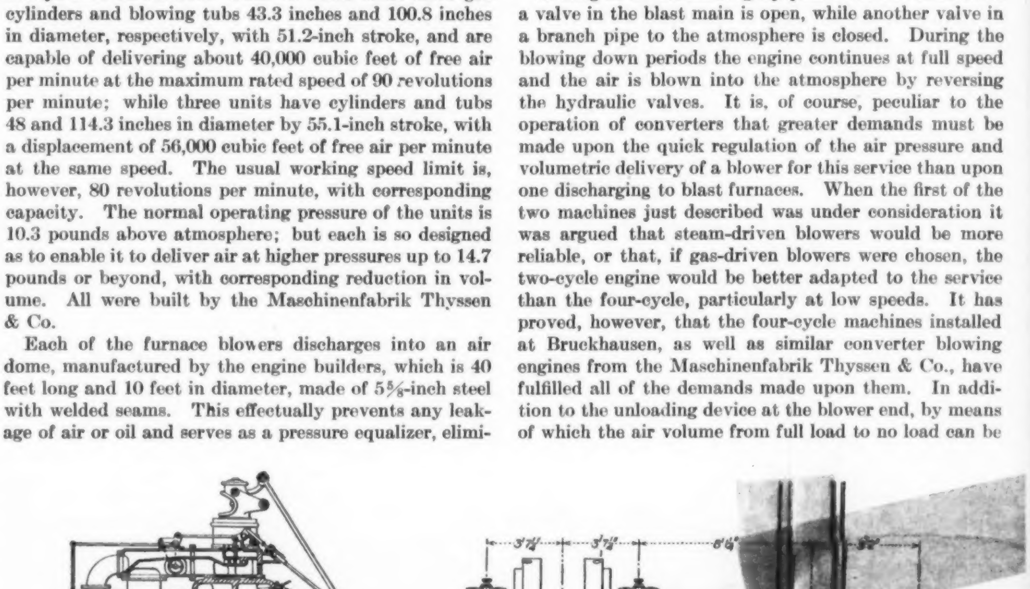


Fig. 4.—Cross Sections Through the Thyssen Gas Engine.

instantly varied, with speed constant, the valve gear of the engine is so designed that the speed can be varied at will within wide limits. How closely this latter regulation works is demonstrated by the fact that the machine operates with absolute reliability at speeds as low at 20 revolutions per minute, while the maximum speed, 90 revolutions per minute, can be attained within 20 seconds.

Greater demands cannot be placed upon even a first-class steam blowing engine, and it is self-evident that these characteristics have put the four-cycle gas blowing engine in a position to compete successfully also with steam turbine driven or motor driven turbo blowers or two-cycle gas blowers. According to figures given to the writer by the Maschinenfabrik Thyssen & Co. some time ago, they have already built over 200,000 horse-power in machines of this type. They also make a point of the fact that, in addition to equal service reliability, the four-cycle gas blowing engines have about three-fold the efficiency of steam-driven blowers and lead the two-cycle gas blowing engines in mechanical and thermal efficiency together by 8 to 15 per cent. There is also the further benefit, in comparison with steam turbine-driven blowers that a condensing system with high vacuum is essential to the successful operation of a turbine plant, and this requires a large quantity of cold water, or about eight times as much for a gas engine of the same capacity, which in many places can only be obtained at high cost.

The works of the Gewerkschaft Deutscher Kaiser include extensive coal mines, some of the shafts of which open upon the plant area; a large coke and by-products plant; six blast furnaces recently remodeled, with inclined electric skips hoists, bell tops, etc.; a nine-furnace Siemens-Martin open-hearth steel plant; a basis Thomas converter plant of 5 to 16-ton units; new electric refining furnaces; two blooming mills, seven finishing mills, etc., as well as allied fabricating, founding and machine plants under the control of the owners, viz., the Thyssen interests, which, next to the Krupps, are the largest of the German metal industries.

The Maschinenfabrik Thyssen & Co., one of these interests, has gone extensively into the manufacture of large gas engines and claims to have built more of these than any other European concern, or a total of upward of 400,000 horse-power, including the blowing engines mentioned above and 180,000 horse-power in electric units, all since 1906.

In the preparation of this article the writer is indebted for the description of the cleaning plant and considerable other data to H. J. Freyn, who made a much more thorough inspection of the Bruckhausen power system than the writer did, and whose work in connection with the largest gas engine installations in the United States is well known. It will also be worth while for any one having a practical interest in blast furnace gas power plants to compare the results described above with those given by Mr. Freyn in his paper read before the American Society of Mechanical Engineers on the plant at the South Chicago Works of the Illinois Steel Company. This was published in June, 1910.

The Planet Mars*

The Reality of Its Markings

By James H. Worthington

Before entering upon the subject of this article, it is advisable that I should state in a few words why it has been written and precisely how the information which it contains was obtained. Being much impressed by what I had read of the Martian features, as detected and portrayed by Lowell and Schiaparelli, I determined to avail myself of the first opportunity, if possible, to see for myself whether or no these features were real, because they seemed to be too wonderful to be believed at second hand. The opportunity came in 1909. Thanks to Lowell's hospitality and kindness, I was able to study the planet at Flagstaff during the opposition of that year and was fortunate enough to see many of the canals and oases and to assure myself of their reality. On returning to Europe in 1910, I found much scepticism prevailing which I scarcely knew enough to refute. I therefore attempted and partially succeeded in seeing the canals again at Nice. This was in 1911.

When the planet again approached opposition, I gladly accepted Lowell's invitation to see more at Flagstaff and accordingly spent two months there, observing the canals and studying them in greater detail. I was able to confirm Lowell's observations and by discussion with him to remove from my mind many obstacles which stood in the way of accepting not only the discoveries but also the explanations which he has put forward.

Having had freedom to travel, I have been able, owing to the courtesy shown to me by many astronomers on my journeys, to study, with the aid of exceptional facilities, the effects of climate upon the astronomical work—a factor the enormous importance of which can scarcely be realized by those whose experience is confined to a single country or even continent.

It seems to me therefore that I may be able to add a few words of interest to the great mass of accounts which have appeared recently upon this most engrossing subject.

From the earth no celestial body is more accessible to observation than Mars, the moon alone excepted. To this proximity is due, in large measure, the exceptional success which has rewarded our study.

At the outset of this inquiry it should be remembered that in space all positions are unique both in their conditions and opportunities. It is therefore necessary, as far as possible, to free our minds from the prejudices which are due to our position and to study the details which have been revealed to us with dispassionate coolness.

It being in the nature of man to seek his likeness, he seeks it before all else, forgetting that when dealing with another planet the one thing which is *a priori* probable is that he will find much that is quite different and so he comes to consider strangeness as one of the hall marks of truth in his discoveries.

Geomorphic ideas have led men into many errors. The so-called seas of the moon have turned out to be the driest of land and the greenish areas on Mars, at first so confidently dubbed oceans, in the light of further research, appear not to be fluid at all.

Thus are we taught to expect the unexpected, and to feel no surprise when three centuries of patient study are rewarded by its discovery in Mars.

With the invention of the telescope came the discovery of the nature of the planets as comparatively cool bodies reflecting to us the light of the sun—a discovery which was announced in the famous anagram of Galileo:

Cynthiæ figuras æmulatur mater amorum.

(The mother of loves [Venus] imitates the phases of the moon.)

In later days his most distinguished compatriot Schiaparelli might well have used his predecessor's words with equal aptitude to express the result of recent work on Mars:

Hæc immatura a me jam frustra leguntur.

(As yet I seek in vain to read the meaning of these incomplete observations.)

It fell to Galileo in the end to expound his epoch-making discovery. The same justification came to Schiaparelli, for though his eyes failed him, he lived to see through those of his successors the confirmation, extension and interpretation of his work.

Soon after the discovery of the disk of Mars, came the announcement from Huygens that the disk possessed surface features from observation of which he felt assured that, like the earth, the planet rotated upon an axis. The marking which revealed this fact is the now well-known dusky wedge called the Syrtis Major.

A little later increased telescopic power showed to the old observers the white areas covering the poles of the planet whose behavior has turned out to be the master key to the explanation of almost all the detail on the disk which subsequent scrutiny has revealed.

But space does not permit me to follow historically all the steps by which we have acquired our present knowledge of the planet. Sufficient has been said to show that it has advanced *pari passu* with the power of optical instruments.

The investigators who preceded Schiaparelli laid the foundations of areography, as the subject is named which describes the configuration of the Martian surface features—patches of color, green and ochre, white and gray, which cover the disk with their varied hues, making it appear like a gigantic gleaming opal. On looking at Mars we perceive them at once. Their outlines are well defined and have long since been laid down in maps of the planet.

The delineation of these features was well-nigh complete when Schiaparelli began his studies of the planet in 1877. The opportunity then afforded was an exceptionally favorable one, the planet being very near the earth when showing the fully illumined face of opposition.

At this time the disk was so much dilated by its proximity that with a magnifying power of only eighty diameters it appeared in the telescope as big as that of the moon seen by the unaided eye. Schiaparelli and the world alike were startled on this occasion by the discovery of numerous dark lines criss-crossing in the most unexpected fashion the ochre-colored regions of the planet.

Following the well-worn analogy of his predecessors—of land and sea areas on the planet—he christened these new features "canali" or channels, which reckless translators at once dubbed canals, a name implying more than the astronomer had actually found on the planet.

At each subsequent opposition he succeeded in seeing them again—and seeing them better with growing experience, he added to their number and complexity the fact that many of them consisted of doublets the two component lines of which were rigidly parallel.

Those who could not see the "canali" at all very naturally refused to give credence to them and began to suspect that they were the illusions of their discoverer.

As first seen by Schiaparelli, they were not by any means very regular but as his powers of discrimination increased with practice, he perceived more and more clearly their linear and geometric configuration.

To see these markings at all implies a very great advance in the observer's art, as is proved by the fact that even to this day, though their existence is no longer questionable or questioned, there are few observers who have seen them as well as did their discoverer more than thirty years ago.

The object of this article being to present concisely an account of our present knowledge of the planet, we shall do well to proceed at once to study the methods used by Lowell—Schiaparelli's greatest successor—and the results which he has obtained. Lowell has added more to our knowledge of the planet than the sum total of all that we previously possessed.

At his observatory the mathematical appearance of the "canali" has been confirmed and the discovery of an equally amazing and correlated system of spots—which he calls oases—has been added.

Another advance was made by the detection in the green areas of the uninterrupted continuance of the network of the "canali," thus showing them to be limited in extent only by the surface of the planet on which they occur.

In order to appreciate the weight of conviction which these discoveries carry, it is necessary to enter somewhat minutely into the means and methods by which they have been achieved. I shall therefore describe them as best I may.

It is often thought, by those unfamiliar with planetary observations, that the larger the telescope the more detail it should reveal; the first step therefore will be to remove this cardinal misconception by a careful consideration of the optical principles involved in the scrutiny of detail upon a planetary disk.

The problem may be succinctly stated as follows: Given a planetary disk, brilliantly illuminated as in Mars: required, the aperture and magnifying power which will best reveal fine detail upon its surface. It is necessary to digress at once to inquire what happens when we turn the telescope upon a star.

The star disk seen in the telescope is a diffraction effect produced by the lens. It is sufficient for the present purpose to recall the fact that the larger the aperture of the lens, the smaller is this diffraction disk; but besides the disk there are concentric rings surrounding it arranged in order of brightness, the faintest visible being the outermost.

Now let us suppose that we wish to separate two bright stars which are very close together. In a large telescope they appear perhaps as two disks either in contact or overlapping with their respective systems of diffraction rings interlacing. The confusion apparent to the eye in this picture is further increased by any unsteadiness in the air between us and the star, which causes the two images to swim and flicker; the rings break and mingle, so that the observer is unable to see anything clearly, the stars appearing as a single pool of boiling light.

The nature of the movements of the air must therefore be considered. These consist of a series of ripples or waves passing across the field of view, whose size may be estimated from the nature of the disturbance they produce. An analogy may illustrate the point.

Any one who has been out in a boat has seen the sea bottom in the shallows on a calm day and noticed how the small objects on the bottom—shells and stones—appear to swing about below on account of the waves. This swaying does not disturb the outlines of the small objects that are visible but merely produces a general rhythmic motion. But if a little breeze ruffle the surface

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of the water, the minute ripples immediately shatter the image of shells and rock, leaving nothing visible but a confused mass of color.

Now the analogy between the watery ocean on the earth's surface and the airy ocean above it leads us to expect kindred disturbances; whether we look down through the one or up through the other, like Newton we may learn something from the pebbles which fringe their mutual margin.

In looking through water—if the attention be confined to a small area—no perceptible distortion of bottom detail is produced by big waves. And so it is with the air also.

Telescopic vision is only concerned with those vibrations which produce disturbance in its field.

Since aerial waves may be of any size up to many yards long, it is obvious that their disturbing effects may be best avoided by the use of a small telescope.

In practice it is found that when a telescope three inches in diameter is used these distrurbances are generally negligible. Contrasting this small instrument with a three-foot telescope, we see at once how much more we may expect to suffer. If it be assumed that the air waves at the moment are a foot across, then to the smaller instrument they are big waves of which only part of one is in the field at any moment. They will therefore produce general motion but being intrinsically small the motion may well be imperceptible, both on account of its minuteness and extreme rapidity.

The case is very different however in the larger instrument. Here are waves much shorter than the diameter the lens and since every part of the lens contributes light to form the image there are at the focus the integrated effect of three waves or at least six different phases of disturbance superposed upon one another and producing inextricable confusion.

In this case there is no general motion but instead a continuous blurring of the image. It therefore appears that since air disturbance is inevitable it is best to seek that which is longest and that which is least in amplitude. If the wave be very big, it will produce only an occasional swaying motion of the image which in no way disturbs the integrity of its parts.

We are now in a position to remove the first difficulty there is in viewing the supposed double star—by stopping down the telescope until the image is free from blurring and subject only to general motion.

We accordingly stop down the telescope and the star now presents the appearance of a peaceful, oblong patch of light, somewhat fainter it is true and perhaps a little bigger but something which will give our eye a chance.

The stars are not yet separate. The observer is still balked of his aim—by reducing the aperture he has increased the star disks, which now overlap the more and he seems to be in the quandary of Alice in Wonderland when she had reduced herself with the aid of the magic cake so as to get through the little door in the passage and found that she could not then reach up to take the key off the glass table. She saw it clearly through the glass, high above her diminished head. But Alice was not at the end of her resources, nor is the astronomer. Alice reduced herself still further and crept under the door and he may further reduce the light of the stars and so see between them. This time he uses a dark glass, the action of which is at once apparent when the nature of the images is considered.

They are brightest at the center and surrounded by fainter interlacing rings which can well be dispensed with. The tinted glass at once cuts off the light of the rings. It also dims the central image equally all over so that only the brightest part in the middle remains visible. The two middle points of the star images are now seen neatly separated by the gap which previously was filled with the light of their outer edges. So the observer has achieved his purpose in an unexpected way by reducing the light instead of increasing it.

This digression may appear at first sight to have little to do with Mars but it is not irrelevant, for in the telescope the disk of the planet is made up of an indefinite number of luminous points each behaving in exactly the same way as the two star disks first investigated. It, is therefore, easily seen that the same methods must be used in separating the several points upon his surface.

One might at first suppose that the process might be continued indefinitely. But a limitation is set by the apparent brilliance of the surface, because to see clearly the eye requires a certain minimum of illumination; above this minimum the method may be applied whose importance has long been unaccountably overlooked by many observers.

In the light of these facts it is easy to see that aperture plays at best a secondary part in planetary observation, which is restricted by the climatic difficulties by which we are so greatly hampered on our earth.

Experience in many observatories has convinced me that as yet there is not one which is so highly favored in a matter of climate as that of Lowell at Flagstaff, Arizona. At this station (at an altitude of a mile and a half above sea level), not only is the air very steady and clear but there is actually less of it and that only the best part left over the observer's head.

Here is then the best place to determine the limits of useful aperture in planetary observation and the result to which observers have been led here is both instructive and startling, as they have found that, even under conditions so good as to be incredible to those who have not seen them, no advantage in definition is gained by dilating the aperture beyond eighteen inches; and when the conditions are less than the best a very perceptible loss of detail occurs.

It seems probable that until some better climate be found, no very substantial advance can be made in the effective power of our instruments but as yet so little is known of the conditions prevailing in out-of-the-way localities that it is quite likely that diligent search may reveal a better place. Meanwhile we must console ourselves with the knowledge that the optician has done all he can for the problem, having made telescopes much larger than the astronomer can use profitably.

Having made this discovery, we must turn our thoughts from the lens at the big end of the telescope to the man at the small end, whose qualifications must now be examined.

Only those whose profession is the use of their eyes can realize how much training is both necessary and possible and how much the degree of proficiency attained depends upon the nature of the training. Just as musicians are called upon to learn different instruments, so astronomers are called upon to view different objects.

There are two main divisions of visual astronomy—stellar and planetary—differing from each other in as many essentials as do fiddling and piano playing. In the case of a star, the observer knows what he is seeking—namely, a small disk of light; all he needs is to see that the star is there.

The case of a planet is different. The disk is there, it cannot escape notice but we are not concerned with it but with its parts. The glimpses of detail which our troubled atmosphere permits us to obtain are but momentary and therefore one of the first essentials is that the observer shall cultivate quickness of perception as well as acuteness in discrimination. Herein lies the fundamental difficulty of Martian observation which only long practice can surmount.

When the conditions are not the best, only the very quick observer will be able to see anything properly. The canals may flash into sight repeatedly without the inexperienced observer ever perceiving them. He must wait for one of those rare occasions when the detail is steadily visible during a second or two, in order to be assured of its reality. He will thus find out what to seek and believe. It is an old story. To be discovered, a fact must force an entrance into the stronghold of men's minds; when once it has achieved this it becomes a welcome guest.

This fact has been already exemplified in the case of Mars. His satellites required a twenty-six inch telescope and persistent care for their discovery but have often since been seen with telescopes of less than half this size.

Lowell has pointed out that there are two useful extremes in eyesight which cannot meet—defining power and sensitiveness to light. Suitable education of the eye assists by drawing the two extremes nearer together but the possession of either quality in a superlative degree excludes the other.

In the retina on which the image falls there is a structure of rods and cones varying markedly in size and texture in different eyes. Those having the finer texture have also the greater defining power but are deficient in sensitiveness. A photographic analogy may help. Rapid plates are more sensitive to light and of coarser grain than the slower plates which give a sharper picture. The increased definition on the slower plate is due to the fact that the finer grain produces less distortion of the detail which falls upon it.

To return to Mars. We find at once among observers of the planet a striking contrast. Prof. Barnard, who by his discovery of the fifth satellite of Jupiter (an object of excessive faintness) proved the sensitiveness of his eye, finds himself entirely unable to detect any of the "canali" which are so evident to Lowell.

Of course some of this discrepancy is due doubtless to differences of climate and instrument but there remains a residuum which can only be explained by a difference of eyesight. Fortunately for the elucidation of the problem many—like the writer—possess eyes intermediate between these two extremes, so that to some extent they may share the discoveries of both. Of this I may perhaps be permitted to quote an instance.

Searching for canals at Flagstaff during the opposition of 1909, using a yellow screen before the eye-piece and an aperture of 18 inches, I was amazed, on glancing off the disk to the surrounding sky, to see a minute point of light, which turned out to be one of the satellites. Lowell, when his attention was drawn to it, perceived it also. Canals were visible to him which I could not see and the satellite which had escaped his notice was evident to me.

There are many features visible on Mars which can only be represented by drawings and to make these successfully requires special qualifications of memory in the observer as well as quick and acute vision. To be convinced on this point it is only necessary to read the reports on the recent eclipse of the sun, a phenomenon so fleeting as to serve our purpose well.

As many readers may remember, this eclipse was just total on the central line in Portugal during perhaps a second, certainly not much more. I quote from an observer who was very near this central line. Referring to the orientation of the solar crescent in mid-eclipse he says: "In the excitement of the moment I did not see whether the crescent of the sun as it passed from the left to the right side of the moon passed below or above it." Again he says: "As the event proved we were too far southeast to be in the track of totality."

It is certain from his position that the crescent did pass on one side only of the lunar disk. Further it is clear that the passage of the crescent must have been comparatively slow, occupying at least a large fraction of a second. Also the observer was not without experience, as he was observing a total eclipse for the fourth time. It is therefore evident that the omission which he so honestly admits was not one of eyesight but of memory.

As has been said, the best views of Martian detail seldom last a second. The positioning of this detail is of the same order of difficulty as the observation quoted.

The next point which claims the attention of the observer is his skill, which means command over the materials which he uses. Many misconceptions of the appearance of Mars have arisen from the extreme difficulty of drawing the delicate detail that is seen. We have only to look at various drawings by different observers to be assured of this. Comparing the drawings, it is difficult to believe them to be *bona fide* attempts to portray the same object.

Lowell tells me that after twenty years of practice in this particular work, he is quite unable to draw the canals of Mars as they appear in the telescope. His practised hand cannot trace lines on paper fine enough or straight enough to represent them. It is therefore natural that the attempts of less experienced observers should be but caricatures of the planet which they strive to represent. It is however a relief that the drawings made independently at Flagstaff do resemble one another and the planet very closely, thus affording internal evidence both of the reality of the features seen and the accuracy of the representations.

Turning now to the method by which detail is detected, we find that the process, unlike the announcement of the discovery, is not a sudden one. Let us follow the observer to the dome and trace his method. Armed with a suitable dark glass and an appropriate aperture, as explained earlier, he watches the planet carefully. Suddenly he is startled by the appearance of some previously unknown marking which flashes into sight but for a moment and is gone, leaving only a vague impression of something being there. The hint so obtained must be noted, for perhaps, later on, another and another glimpse may be obtained which by their cumulative effects assure us of the reality of the new feature.

This is the manner in which all the canals have been discovered and just as accumulated observations establish their numbers, so accumulated hints attest the existence of the fainter markings, until a moment of perfect seeing shows them in all their beauty with the fineness and fixity of a steel engraving.

At first sight their elusiveness suggests an illusion, which accordingly claims our attention next. Optical illusions may be divided into two classes—those which are self-confessed and obvious; and those specious appearances of reality which may deceive all but the most penetrating analysis.

As an illustration of the harmless class of illusion, irradiation may be taken, which is the apparent enlargement of a bright disk when seen against a dark background. By trial of the different contrast effects to which this phenomenon is due, its laws may be determined and its effect eliminated from observations which it might otherwise vitiate.

An instance of the deceptive illusion is the often-quoted power of the eye of integrating minute markings too small to be severally visible. On looking at a mass of small specks too small to be seen clearly apart, the eye has a strong tendency to accept the specious appearance of these as lines and they cannot be distinguished from realities except by the closest scrutiny. Happily this illusion is only possible under critical circumstances of distance on the narrow borderland between seeing the dots as they are and not seeing any trace of them.

Now the lines which skilled observers have perceived on Mars have been seen under many varied circumstances of distance, illumination and instrument. It seems therefore impossible that they can be due to this form of illusion. Also it is certain that though a series of dots may masquerade as lines, the converse action is inconceivable. Since also dots and lines are visible on Mars at the same time—oases and canals—the assumption of the reality of both seems warranted.

Weighing the Atom

Sir J. J. Thomson's New Method of Chemical Analysis

By F. W. Aston, B.A. B.Sc., A.I.C.

[In an early issue of this year's volume we had occasion to publish an address delivered by Sir J. J. Thomson on his new method of chemical analysis. We present now a paper recently published in Science Progress, giving some further detail of the method. This represents one of the most remarkable achievements of one who has contributed to modern physics some of her greatest triumphs.—Editor.]

No observer of the progress of "Molecular" Physics and Chemistry during the past decade or so can fail to have been struck by the extraordinarily intimate knowledge we have acquired, especially recently, of Atoms and Molecules—the individual units of complex matter. The results serve to confirm the shrewd estimate made by a great scientific thinker like the late Lord Kelvin that molecules are indeed almost inconceivably small compared with the masses of matter affecting our senses in everyday life. Thus the consensus of a variety of methods shows that a thimbleful of the air we breathe contains about a thousand million million million molecules, the average diameter of each of these being one hundred millionth of an inch; or to give a more practical illustration, a molecule of carbon in the paper upon which this article is printed subtends to the reader's eye the same angle as would a normal human being at the distance of the moon.

To hope that an effect appreciable to our senses could be produced by a body so minute as a molecule would therefore at first sight seem absurd, yet this has been done in several notable instances in a most convincing manner. Thus in the spinthariscope of Sir William Crookes we actually see the flash of light caused by the impact of a single α ray (which is a charged molecule of helium) upon a screen of zinc blend. Rutherford and Geiger have shown the measurable "kick" of a delicate electrometer due to the ionization produced by a similar α ray. While C. T. R. Wilson, with the aid of an apparatus recently exhibited at the Royal Society, has been able, in the most beautiful manner possible, both to see and to photograph the track of a single charged molecule.

The explanation of such large effects as these lies in the fact that the charged molecule constituting an α ray is moving at so prodigious a velocity that in its collision with other material particles it is able to set free a quantity of energy out of all proportion to its mass; it is this Kinetic Energy or power of doing work, $mv^2/2$, which may be made appreciable by sufficiently increasing the velocity factor v, although the mass factor m may be inconceivably small. It is on this account that the helium molecule of mass 6×10^{-24} of a gramme, when moving with a velocity 2×10^9 centimeters, i. e., about 100,000 miles per second, is capable of causing a flash of light appreciable to the eye when it strikes a fluorescent screen.

The novel and remarkable method of chemical analysis which is the subject of this article depends upon the fact that if we can communicate high enough velocities to molecules they will be able to produce appreciable and permanent effects when falling upon suitable material; also upon the fact that if such moving molecules can be electrically charged they become amenable to externally applied electric and magnetic forces and by their movements under these forces can be made, in a phrase, to *weigh themselves*. The method, indeed, is different from all other chemical methods of determining molecular mass, in that it deals with the individual molecule and not with large numbers.

It is the outcome of a long and exhaustive series of researches upon the nature of Positive Electricity which Prof. Sir J. J. Thomson has been pursuing almost continually since he revolutionized modern views on electricity by his classical experiment with cathode rays, from which he inferred that negative electricity occurs as definite units, corpuscles or electrons, the mass of which is one eighteen-hundredth part of that of an atom of hydrogen. The principal field of these researches has lain in the so-called "Kanalstrahlen" or Rays of Positive Electricity which Goldstein, as long ago as 1886, observed in a vacuum tube provided with a perforated cathode.

These rays were investigated afterward by Wien, who showed that some of them at least carried a positive charge and had a mass of molecular order: it has, however, been the task of the head of the Cavendish Laboratory to explore, in a detailed and accurate manner, this wide and complex field of research. The subject of the present article is but a single offshoot of the work. It will be of interest to those who are unable to follow the original papers on the subject to know the method by which it has been demonstrated that just as light from a flame can be split up by a prism into a spectrum showing the chemical constitution of that flame, so positive rays emerging from a perforated cathode can be resolved, in like manner, so that the several constituents of the gas in the discharge tube become obvious.

In order to apply the method to a gas, its particles undergo the following operations:

1. They are given a definite charge of electricity.
2. They have a high velocity impressed upon them in a definite direction.
3. They are allowed to pass through an electric and a magnetic field.
4. Finally they fall upon a fluorescent screen, a photographic plate or some other suitable arrangement capable of recording the exact positions of the impacts.

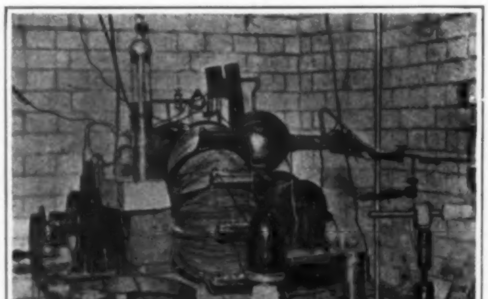


Fig. 1.

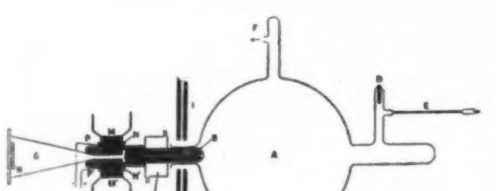


Fig. 2.

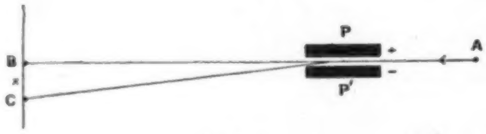


Fig. 3.

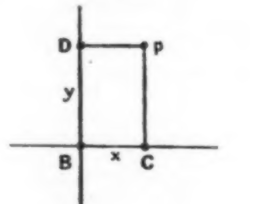


Fig. 4.

Fortunately the first two conditions are fulfilled at the same time and automatically by submitting the gas to a high-tension electric discharge at low pressure. The gas is "ionized" by this treatment and the positive ions are projected with prodigious velocity toward the cathode; if this be pierced with a small hole, so as to allow of their free passage, they will emerge on the other side as a stream of positively charged particles which may then be acted upon by the analyzing fields.

It will be as well now to describe the particular form of apparatus which has been found to give the most satisfactory results. The main features are shown in the accompanying diagram (Fig. 2). The discharge tube A, which is very similar to an ordinary X-ray bulb, is a large spherical flask about 1½ liters in capacity. Pushed into the neck of the flask and closely fitting it is the cathode B: this is made of aluminium and is so shaped that it presents to the bulb a hemispherical front provided in the center with a funnel-shaped depression. The long, fine "canal-ray" tube extends from the bottom of this depression. If carefully centered and fixed so that its hemispherical head just projects into the bulb, this type of cathode gives a very intense beam of positive rays down its axis, i. e., into the "canal-ray" tube. The latter has been made in several different ways: as the accuracy of the method depends on the fineness of the emergent beam, it is essential that the tube should be perfectly straight and extremely fine. The best results have been obtained with brass or copper tubes drawn down until their internal diameter was of the order of 0.1 millimeter. The fine tubes are most carefully straightened, tested by sighting a bright light through them, and mounted in a thick soft-iron tube (shown black in the diagram), which not only protects them from injury but also effectually shields the rays passing through them from external magnetic fields; the latter is a very important point, as in so narrow and long a barrel—80 millimeters is a convenient length—the smallest magnetic deflection would be sufficient to drive the particles against the walls of the tube and so prevent them from emerging. The cathode is kept cool during the discharge by means of a small water-jacket C.

The anode of the discharge bulb is an aluminium rod D, which is generally placed for convenience in a side tube. In order to insure the gas under examination being as nearly pure as possible and also to keep its pressure constant, a steady stream of the gas is allowed to leak through an exceedingly fine glass capillary tube E and after circulating through the apparatus is pumped out at F by a Gaede rotating mercury pump. By varying the speed of the pump and the pressure in the gas-holder communicating with E, the pressure in the discharge tube may be varied at will and maintained at any desired value during considerable lengths of time. The pressure is usually adjusted so that the discharge potential corresponds to a spark-gap between brass balls 1 to 2 centimeters apart in air, i. e., 30,000 to 50,000 volts. Positive ions, i. e., particles of gas carrying a positive charge of electricity, are formed in A by the discharge which is maintained by a large X-ray coil made by Cox. Under the influence of the enormous electric field, they attain correspondingly high velocities and those which fall axially upon the cathode pass through the narrow "canal-ray" tube and emerge as a fine beam of "canal-rays."

The charged particles traveling in a definite direction at a high velocity, are subjected to the analyzing influence of electric and magnetic forces by causing the beam to pass between the pieces of soft iron P P' which are placed between the poles MM' of a powerful electromagnet. P and P' constitute the pole pieces of the magnet but are electrically insulated from it by thin sheets of mica N N' and so can be raised to any desired electrical potential difference by means of the leads shown in the figure. As the rays pass between the faces of P P', they are subjected to the influence of electric and magnetic forces simultaneously and after they have been analyzed, in a manner to be described later on, they enter the "camera" G and finally impinge upon the fluorescent screen or photographic plate H. In order that the stray magnetic field may not interfere with the main discharge in A, shields of soft iron, I I, are interposed between the magnet and the bulb.

Fluorescent screens made of powdered Willemite were used in all the earlier experiments but as these only show the impact of the rays very faintly in a dark room and give no permanent record, they are unsuitable for the purpose of accurate measurements; a notable advance in technique was made by the use of photographic plates. When exposed to a beam of positive rays, the surface of such a plate undergoes a chemical change of a nature somewhat similar to that caused by actinic light and may be developed in the ordinary way, a more or less intense deposit of silver being formed wherever it has been struck by the rays. The plates which have been found to give the best results are the well-known Sovereign brand made by the Imperial Plate Company. The most convenient way of exposing the plate is to use a device which the writer has used previously in other experiments requiring accurate movement of an object in a high vacuum. It is roughly indicated in the accompanying figure (Fig. 5), which shows the complete camera. The photographic plate is placed in a light frame supported by a silk thread; the frame can be wound up and down by means of a winch the axle of which works in an air-tight, ground joint. While the

pressure, etc., is being adjusted, the plate is kept at the top of a light-tight metal case and as soon as the fluorescent screen at A (Fig. 5) shows that the desired conditions have been obtained the plate is lowered into the field of the rays and a photograph taken. The

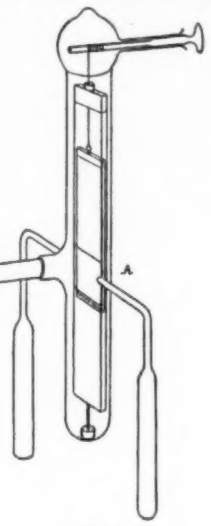


Fig. 5.

exposures depend almost entirely on the diameter of the canal-ray tube and vary from three minutes to three hours. By the use of a long plate, as many as three photos could be taken before it was necessary to destroy the vacuum in the apparatus and introduce another plate. As it is usually desirable, for reasons which will be explained, to have as low a pressure as possible in the "camera," one or two Dewar charcoal tubes are attached to it and are immersed in liquid air while the photograph is being taken. As gas can only enter through the fine canal-ray tube the pressure in the camera may be very much lower than in the bulb.

The accompanying half-tone Figure 1, which is from a flashlight photograph taken by Mr. Hayles, of the Cavendish Laboratory, conveys a good idea of the actual appearance of an apparatus set up by the writer with which a great many results were obtained. On the extreme right can be seen part of the gas reservoir and just behind this the very fine capillary tube which allows the gas to leak slowly into the discharge bulb shown on the right of the large Du Bois electromagnet. In a corresponding position on the left of the last is the "camera" made of glass tube partially covered with paper; this contains the plate-holder and supports at the top the glass "winch" by which the plate is raised or lowered. Behind the magnet may be seen the Gaede pump and the induction coil. Attached to the camera is the large Dewar charcoal bulb, which is cooled by immersion in the vessel of liquid air; the last stands on the table, together with an accurate ammeter for measuring the current flowing through the magnet and a red photographic lamp for use during the removal of the plate when the exposure is ended.

The endeavor may now be made to explain, as briefly and simply as possible, how by subjecting the moving charged particle to an electric and a magnetic field, each at right angles to its path, both the velocity and the mass of the particle may be deduced.

Let A (Fig. 3) be such a particle of mass m, carrying a positive charge of electricity e and moving with velocity v in the direction A B. If this particle be not influenced by electric or magnetic forces, it will obey the ordinary laws of motion and move in a straight line, striking a distant screen at a point B. If, however, we cause it to pass through an electric field of strength X between the plates P P', it will be deflected away from the positive and toward the negative plate in the plane of the paper and finally strike the screen at some other point C, the displacement B C = x being given by the equation:

$$x = k_1 \frac{Xe}{mv^2}$$

If now the electric field be cut off and P P' made the poles of a magnet of field strength H, the moving particle will be deflected *at right angles to the plane of the paper* a distance y given by the equation:

$$y = k_2 \frac{He}{mv}$$

k_1 k_2 being constants depending solely on the dimensions and form of the apparatus used.

If a continuous stream of particles, all of the same mass, carrying the same charge (or what amounts to the same thing in this case, having the same *ratio m/e* of mass to charge) and moving with the same velocity, strike the screen shown in plan in Fig. 4, which is covered with a layer of powdered Willemite, a substance that fluoresces strongly under the influence of the rays, a bright patch of light is produced at the point B, due to undeflected rays, when neither the potential nor the magnet is on. The plates P P' being vertical, if the electric field only be on, the spot will be deflected to C; if the magnetic field only be on, the spot will be deflected to D, but if both are on together to a point p' of which the horizontal and vertical displacements are x and y respectively. It is therefore only necessary to measure x and y and from the equations given above it follows that x is inversely proportional to the kinetic energy of the particle and y inversely proportional to its momentum and that

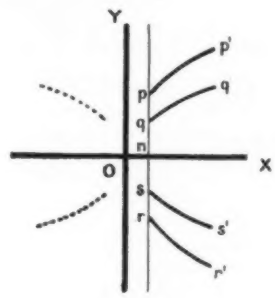


Fig. 6.

y/x is a measure of the velocity of the particle;

y^2/x is a measure of $\frac{m}{e}$ or the ratio of mass to charge.

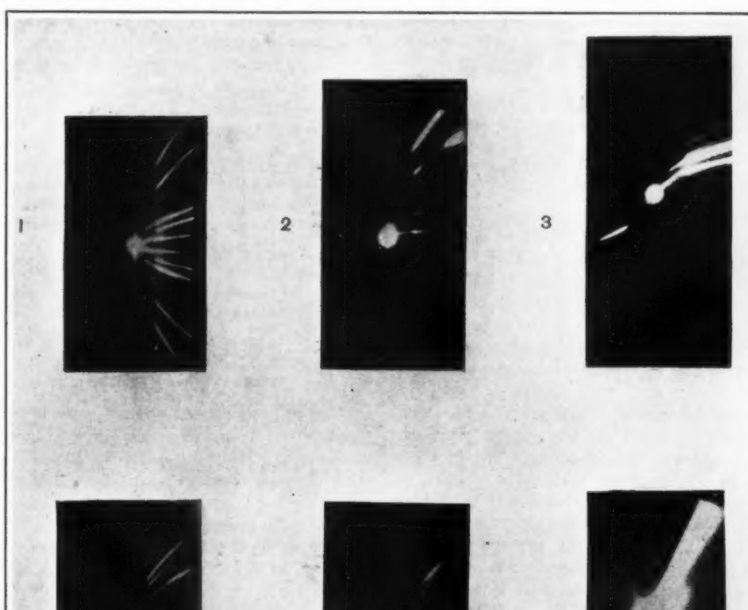
Now e can only exist as a multiple (and in general only a small multiple) of the charge on a single corpuscle and all the evidence up to now shows that this is invariable and indivisible. Thus, if we have a beam of positive rays of constant mass m but moving with velocities varying over a considerable range, y^2/x will be constant and the spot of light will be drawn out into a parabola p p^1 (Fig. 6). When other rays having a larger mass m^1 but the same charge are introduced into the beam, they appear as another parabola q q^1 having a smaller magnetic displacement. (If the range of kinetic energy be the same for both particles the electric displacement will be the same.) If any straight line p, q, n, be drawn parallel to the magnetic axis O Y cutting the two parabolas and the electric axis O X in p, q, n, it will be seen at once that

$$\frac{m^1}{m} = \frac{pn^2}{qn^2}$$

That is to say, *the masses of two or more different particles can be compared directly by merely measuring two lengths the ratio of which is entirely independent of the form of the apparatus and the experimental conditions.*

This is really the fundamental principle on which the method is based. A photograph is taken in which we can identify at least one parabola as belonging to a set of particles of known mass; all the other parabolas can then be measured and compared with this one and their masses deduced. In the case of the lighter particles, the hydrogen atom and the hydrogen molecule are taken as the standards; in the case of heavier particles, the mercury atom is particularly useful as a standard, as it is almost always present and for some reason at present unexplained gives a very bright curve. In order that there may be no possible doubt as to the identity of the H and H_2 parabolas, the absolute value of m/e for these lines has been determined and found to correspond to the values obtained by other methods for the hydrogen atom and molecule.

To return to the diagram (Fig. 6), since O X is an imaginary line and has no existence on the photograph, in order that measurements may be made with greater convenience and accuracy the magnetic field is reversed during the second half of the exposure when—in the case we are considering—two new parabolas will appear



Positive Ray Spectra.

1. Nitrogen. 2. Hydrogen. 3. Oxygen. 4. Carbon Monoxide. 5. Helium. 6. Helium, at higher pressure. 7. Mercury. 8. Mixture of Hydrogen and Oxygen.

at $r\ r^1$, $s\ s^1$, due to m and m^1 respectively; the masses can be compared by the equation:

$$\frac{m^1}{m} = \frac{pr^2}{qs^2}$$

p, q, r, s being any straight line cutting the curves approximately parallel to the magnetic axis. The measurements of these lines is independent of zero determination and if the curves are sharp can be carried out with considerable accuracy.

It has been shown that the electrical displacement is inversely proportional to the kinetic energy of the particle. Since this kinetic energy is simply dependent on and proportional to the electrical potential through which the charged particle fell before it reached the cathode and not upon its mass, in general there will be a definite maximum kinetic energy corresponding to the whole potential drop across the Crookes' Dark Space in the discharge tube, with a corresponding minimum displacement on the plate; so that the parabolas will end fairly sharply at points p, q, etc., equidistant from the magnetic axis $O\ Y$. From the same reasoning it follows that, the farther the parabola extends away from this limiting tip, the larger must be the range of voltage through which the particles forming it have fallen.

Such true parabolic curves as we have considered are caused by positive rays which have retained their charge unaltered throughout both the electric and magnetic field and are termed Primary Positive Rays. Unfortunately a simple interpretation of these is impossible, as the pressure in the camera is seldom and in the canal-ray tube never entirely negligible, so that owing to the intense ionizing effect of the rays on the small amount of gas present in these localities free corpuscles are always to be found there, the result being that the behavior of the positively charged particle is complicated in the following ways:

It may pick up a single negative charge and becoming neutral may pass the fields unaffected and strike the plate at the origin 6, the "undeflected spot."

It may pick up yet another negative charge before emerging from the canal-ray tube and by retaining this throughout the fields may become a Negative Primary Ray and give rise to a parabola similar in all respects to the positive ones but in the opposite quadrant, as shown in Fig. 6 by dotted lines.

It may be changed from a neutral to a charged particle of either sign or vice versa *during its passage through the fields*, thereby giving rise to rays which do not strictly obey the fundamental equations, as the values of X and H which affect them will not be constant but will depend on the position of their origin or destruction. These are called "Secondary Rays." The effect of these rays on the photograph or screen is exceedingly complex; indeed in the earlier experiments they completely overshadowed the genuine primary rays, so that it was only by designing apparatus in which the pressure in the camera could be kept low that the primary rays could be seen distinctly. Even with the apparatus in its present state, it is impossible to eliminate them entirely, especially when gases such as hydrogen or helium are present which are not completely absorbed by the cooled charcoal. Owing the the presence of secondary rays, the greatest care must be taken in interpreting the photographs, as the secondary rays may give parabolas which under certain conditions are quite indistinguishable from the true primary parabolas. Fortunately the relative positions of these false curves are usually changed when the photograph is repeated under slightly different experimental conditions. It is then possible to detect them, as no such change in the relative positions of the true primary parabolas is ever noticeable. The object in maintaining the lowest available pressure in the camera is to eliminate secondary rays as far as possible.

It will now be well to consider a few of the actual results in detail. The accompanying plates are reproductions from the original negatives and illustrate several typical cases. Plate I was obtained with nitrogen (made from air) in the tube, the magnetic deflection being small enough to show the two hydrogen lines. It will be seen that there are five very bright lines in each side of the magnetic zero; if the most deflected line be of mass unity, taking the squares of their relative deflections, the other lines correspond to masses approximately 2, 14, 28, 200. The five lines are evidently due to the hydrogen atom and molecule, to the nitrogen atom and molecule and to the mercury atom, respectively, each presumably carrying a single charge.

All the parabolas end off approximately at the same distance from the vertical axis through the bright undeflected spot: that corresponding to the nitrogen atoms, however, has a distinct "beak" or feebler continuation which ends half as far away and therefore must be caused by particles having twice the kinetic energy of those causing the brighter part. It is quite impossible to suppose that these are due to nitrogen atoms which have fallen through twice the voltage, as the actual maximum voltage of the discharge tube never rose appreciably above that corresponding to the tips of the other parabolas; the most probable explanation is that the atoms of nitrogen forming the extension of the curve carried a double charge $+2e$ while coming up to the cathode and therefore reached it with twice the normal kinetic energy. If during their passage through the canal-ray tube they picked up a single negative charge $-e$, they would emerge as atoms with a single positive charge and so would fall upon the same parabola but at a distance half as far away from the magnetic axis. If this view be correct, we might expect some of these doubly charged atoms to retain both charges throughout the fields; they would then behave exactly as would particles of mass 7 with a single charge $+e$, as the position of the parabola depends only on the *ratio* m/e. On looking for such a parabola, it can be seen clearly between the nitrogen atom and the hydrogen molecule, though it is naturally rather faint. Similar evidence of doubly charged particles will be seen in several of the other plates.

Though the negative in Plate I is a good one to reproduce in print and to illustrate the general characteristics, it is by no means the best type for actual measurement, as the lines in it are much too thick and bright. It would be quite impossible to reproduce satisfactorily the plates with which the best metrical results have been obtained, as a line can be measured with great accuracy if the canal-ray tube be sufficiently fine even when it is only just visible on the negative.

For measuring purposes the negative is clamped in a special apparatus and a needle, mounted on a slider so that its point just does not touch the gelatine, is moved across the parabolas in a direction parallel to the magnetic axis $O\ Y$ (Fig. 6); whenever the needle lies exactly over a parabola, its position is read on a vernier scale. In the case of a fine line the position can be determined to about 1/20 millimeter.

In order to give some idea of the measurements which can be made in this way, the actual records of an experiment with a very fine canal-ray tube working satisfactorily may be quoted.

Gas in discharge tube *air* at about 1/100 millimeter pressure. Potential on plates 166 volts. Current through magnet 2.00 amperes. Exposure 1½ hours. Discharge potential equivalent to sparkgap 1½ centimeters in air; d is the displacement in millimeter from electrical axis; m is the corresponding mass obtained from the inverse square of d expressed relatively to mercury as 200.

d.	*m.*		Probable cause of line.
5.25	200.0	Hg_{+}	Mercury atom with single charge.
7.40	100.2	Hg_{++}	Mercury atom with double charge.
9.15	64.6	Hg_{+++}	Very faint line, possibly mercury with triple charge.
11.30	43.0	CO_{2+}	Very faint, probably CO_2.
14.05	28.0	N_{2+}	Nitrogen molecule (brightest line).
18.50	16.0	O_{+}	Oxygen atom.
19.70	14.1	N_{+}	Nitrogen atom.
21.50	11.9	C_{+}	Carbon atom.
26.15	8.0	O_{++}	Oxygen atom with double charge.
28.1	6.98	N_{++}	Nitrogen atom with double charge.
30.35	5.98	C_{++}	Carbon atom with double charge.
52.2	2.02	H_{2+}	Hydrogen molecule.

(Carbon and its compounds were present as impurities derived from the apparatus; these can only be eliminated with great difficulty by prolonged washing with oxygen. Lines due to such impurities are, as a rule, very faint in comparison with those due to the gases known to be present in quantity.)

Here we have twelve distinct parabolas, not counting that due to the hydrogen atom which has been thrown off the plate by the large magnetic field. Of these all the bright ones fall exactly on positions from the gas that filled the tube, their masses agreeing with the generally accepted molecular and atomic weights to about 1 per cent.

A word of caution may well be given here in connection with the relative photographic intensities of the lines. These are entirely misleading and incorrect, as one might very well expect on seeing that in Plate I hydrogen gives almost the brightest lines in a tube supposed to contain practically pure air. A trustworthy electrical method has been devised recently by which the true relative intensities of the lines can be deduced from the total charges carried by the particles which give rise to them; the results show that a hydrogen line appearing on the plate or screen as the brightest line of the set may really not be one hundredth part as intense as the lines corresponding to the gas with which the tube is filled.

From experiments already made by the electrical method, we may say that roughly speaking the true intensities of lines due to a given gas are proportional to the quantity of that gas present, while the photographic intensity of lines of equal true intensity is far greater in the case of those produced by particles of lighter mass.

To readers interested in chemistry a short description of the specific behavior of a few individual elementary substances may be of interest. To begin with, it is a fact of the very first importance to the student of the nature of electricity that up to now, though every possible scrutiny has been applied, *no positive ray having a smaller mass than that associated with a hydrogen atom has been detected.* Elements of lower atomic weight, if present, make no appearance on the sensitized surfaces used to record the rays, neither does it seem possible for the hydrogen atom itself to carry more than one charge.

Hydrogen.—The lines due to H_{1+} and H_{2+}, largely no doubt owing to their very exceptional photographic efficiency, appear on practically every photograph taken of the part of the magnetic spectrum which includes them. They can be eliminated, however, by thoroughly rinsing out the tube with highly purified oxygen. Oddly enough, considering the chemical properties of the element, atomic hydrogen also appears repeatedly with a negative charge. If hydrogen be mixed with a small percentage of some other gas, such as nitrogen, a very remarkable line sometimes makes its appearance which corresponds to a hypothetical substance H_{3+}. A photograph showing this line is reproduced in Plate II; though it is always faint when compared with H_1 and H_2 the parabola is nevertheless genuine and has been repeatedly obtained.

Oxygen.—This gas has probably been experimented with in a more nearly pure state than any other, as it combines with all the impurities given off by the apparatus forming compounds which can be removed by means of liquid air. Plate III was taken with this gas. H_1 and H_2 have practically disappeared and nearly the whole of the intensity is in the lines corresponding to +16 and +32, O and O_2, respectively. There is a very strong negative line O_- at —16. This O_- line appears on nearly all plates taken when oxygen is present, either free or in combination. No negative corresponding to O_2 has been detected in highly purified oxygen but the line sometimes appears when other gases are present. The very obvious extension of the O_+ line in Plate III indicates the tendency of the oxygen atom to take up a double charge.

Nitrogen appears as N_{++}, N_+ and N_{2+}; it never gives a negative parabola. In some of the nitrogen photographs a faint line is found at 42 to 43 which Prof. Thomson thinks may be due to a compound N_3 or N_3H. If made from air, nitrogen shows the argon line corresponding to mass 40.

Carbon appears as C_{++}, C_+ and C_- when compounds such as the monoxide and dioxide are used. Plate IV, which represents carbon monoxide, shows the negative O and C lines quite clearly and also doubly charged positive ones. On using certain organic compounds, a negative parabola corresponding to a mass 24 is found, which seems to be due to a molecule consisting of two carbon atoms carrying a single negative charge.

Organic compounds give very complex results but it is beyond the scope of this article to discuss these. The case of methane, CH_4, however, is comparatively simple and of particular interest. In the case of this gas, if a very narrow canal-ray tube be used, a group of five distinct parabolas is observed differing from each other by mass 1 and corresponding to C, CH, CH_2, CH_3 and CH_4, respectively, each carrying a single positive charge.

Chlorine and the other Halogens can be used in the form of their compounds with hydrogen or carbon. They are principally of interest because, like oxygen, they give strong negative atomic parabolas.

Helium is associated with a single very strong line of mass 4 corresponding to He_+. As this gas cannot be removed from the camera by the cooled charcoal the secondary effects are usually very strong. Plate V shows the two faint hydrogen lines and the bright helium line. This plate is an admirable illustration of the danger of secondary rays. The apparent parabola just inside the He parabola, which corresponds to a mass 5 and might easily suggest a compound HeH, is really not a primary at all. If the pressure in the camera be allowed to rise rather higher, the effect shown in Plate VI is produced, bright beams of secondaries of both signs being the only visible rays.

Mercury.—This element possesses quite peculiar interest in connection with these results. Its presence in the discharge tube in small quantities is, of course, to be expected, as the apparatus is exhausted by a mercury pump. Should mercury not be required, it can be frozen out with liquid air; in general, however, its presence is an advantage, as the mercury line cannot possibly be mistaken and gives a very valuable standard for measurement. The presence of large quantities of certain gases, notably oxygen and the halogens, involves its complete disappearance. The behavior of mercury is in two ways quite inexplicable: in the first place, although the heaviest of all the elements yet measured, its photographic efficiency seems almost as great as that of the extremely light elements; and what is still more unaccountable, its parabola invariably seems to extend almost to the very origin itself and would require at least three or four charges upon a single atom to account for its enormous kinetic energy in the manner already indicated. Nearly all the plates here show its characteristic line quite distinctly but Plate VII gives the most striking idea of its beautiful parabolic form and remarkable appearance when the strength of the magnetic field is

made extremely high; the electrical displacement due to a single charge can be distinguished as a bright "bead" a short distance along it; the head of the other line (CO_+) in the plate is in the same vertical line. This mercury line 200 is almost always accompanied by the double charged one corresponding to 100, which can be seen plainly in Plate IV. Mercury is unique in that it is the only metallic element, with the doubtful exception of potassium, which as yet has given definite proof of its existence in positive rays.

Plate VIII, which was obtained from a mixture of hydrogen and oxygen under conditions of fairly high pressure in the camera, has been included in order to give the reader some idea of the extreme complexity of the secondary rays, which in this particular instance form a perfect network of lines, straight and curved. Out of five apparently distinct lines on the negative side, only two, the H_1- and O_2- lines, are genuine. For a detailed discussion as to the origin and behavior of secondary rays, the reader is referred to Prof. Thomson's original papers on the subject which have been published from time to time in the *Philosophical Magazine*.

From these few illustrations and brief descriptions, ideas of the possibilities and limitations of the method will doubtless have already been formed. As to the latter, some are obvious, such as the fact that in order to apply the method to the determination of atomic weights the substance analyzed must exist in a state of vapor and be able to support an electric discharge. There is, however, another more subtle disability which is also known to affect ordinary spectroscopic analyses of gases: this is that a substance may be present in quite large quantities and yet its characteristic lines may not be apparent. When it was stated that mercury was the only metal so far clearly identified, it must not be understood that it is from any lack of trying others. As soon as the method was found to afford results of reasonable accuracy, Sir J. J. Thomson endeavored to apply it to settle the much vexed question of the atomic weight of nickel, the value generally accepted by chemists appearing incompatible with the results obtained by physicists on studying the characteristic radiation of the metal. But although nickel carbonyl was passed through the tube and nickel chloride was vaporized inside it, the plates obstinately refused to vouchsafe the least indication of a nickel parabola and results with potassium were very nearly as negative. It seems almost inconceivable that these elements cannot exist as ions in the discharge tube but it is quite possible that they are incapable of retaining their charge after reaching the cathode and so are not analyzable by the method. Another less likely possibility which may shortly be tested is that the parabolas are there but are incapable of affecting the screen or the plate. From the point of view of accuracy, the limitations of the method are almost entirely those of apparatus, design and technique; it is therefore to be supposed that they will be removed as experience grows.

As regards the very special interest and possibilities of the method, in the first place the sharpness of the parabolas obtained, which appears to be only limited by the possible fineness of the canal-ray tube, is the first rigorous and direct proof of an article of scientific faith which has been accepted during many years past without hesitation, namely, that the individual molecules of any given substance all have identically the same mass.

The point which will probably appeal most strongly to the imaginative mind is that connected with the almost inconceivably short time necessary for a particle to exist in order to register its mass. For since a moderate velocity for the positive rays is 10^8 centimeter per second and 10 centimeters is amply sufficient for them to gain their velocity and be deflected by the fields, compounds which have an existence of but the ten millionth part of a second will infallibly be weighed on this impalpable balance. Hence it is that we need not be surprised at finding upon the plates lines corresponding to molecules found neither in the heavens above nor the earth beneath; nor need those of us who are chemists hold up our hands in horror at such unnatural and grotesque monsters of the world of molecules as H_3, CH, CH_2, CH_3, N_3, etc. Rather should we look forward to this line of investigation as an extremely hopeful field in which to study the actual mechanism of dissociation, ionization and chemical interaction. The method is applicable to the most microscopic quantities of a substance at disposal. That it has already yielded interesting results will, I hope, be apparent from this very brief account; there seems to be little reason to doubt that, as the technique of the experiments is improved, results of still greater importance may be looked for.

Safety First—I*

Accident Prevention on Railroads

During the last ten or fifteen years there has been much discussion in the public press, among the people, in the legislatures and in Congress on the question of prevention of accidents by law; and, in pursuance of the theory that the fixing of greater liability on the employer to respond in damages would make them more careful and thereby reduce the number of accidents, employers' liability laws, laws taking away the defense of fellow servant, assumption of risk, contributory negligence, as well as workmen's compensation acts, have been enacted, with the result of requiring the employer to respond in damages, generally for the benefit of lawyers, and occasionally for the benefit of the injured man or his dependents, but without any result worth mentioning in the way of reducing accidents or decreasing the toll of death and injury, which is what the workingman, the employer and the public want and need. How badly some such action is needed is shown by the September, 1908, bulletin issued by the Commissioner of Labor of the United States, which on page 458 shows 35,000 workingmen killed in industrial accidents every year, or one every fifteen minutes of every day in the year, and the injuries at two million every year, or one every sixteen seconds of every minute and hour and day in the year. And contrary to the general understanding, only one tenth of the deaths and one sixteenth of the injuries were railroad men, the other nine tenths and fifteen sixteenths being workmen employed in the other industries of the country. As nothing was accomplished by such laws, some other method had to be adopted, as neither the workingman, the employer or the public could longer stand any such drain of human life, greater than the loss of lives in any one year in that terrible civil war through which we passed fifty years ago.

If the question were put to this assemblage of men as to what was their most valuable as well as most precious possession next to their wives and children, I think I could get a unanimous vote that it was their lives and their limbs, not their bank account, property, their jobs or their credit, and yet our lives and limbs are the very possession of which we railroad men during the last fifty years have been the most careless and about which we have taken the most chances. The railroad list of casualties as shown by the last report of the Interstate Commerce Commission for the year ending June 30th, 1911, was 3,602 railroad men killed and 126,039 injured, or nearly 10 per cent of all the men employed, of which 3,163 were killed and 46,802 injured in operating accidents, and 439 killed and 79,237 injured in industrial accidents, such as accidents in shops, roundhouses, offices, stations and repair yards.

There are, I suppose, many reasons why we have so many more accidents on the railroads of this country than they do abroad, but I think the principal ones are that we are a nation of chance-takers. We take a chance on anything from a horse race up, or down. We have all seen men run across a railroad track in front of a rapidly moving train and when they got over stop and watch the train go by; whereas if they slipped or stumbled and fell in crossing, an injury or death was inevitable. Another reason is because our lines are so much longer than those abroad that it is much more difficult to exercise the same supervision over the men and the property. Another cause is that so many of our men are foreigners and cannot understand or speak our language, making it exceedingly difficult to instruct them how to do the work safely and properly; and as very frequently many of these foreigners think that a free country means a place to do as they please, it is exceedingly difficult to make them do things in the right way, even when we can make them understand.

Now I suppose as long as people are human we will continue to be a nation of chance-takers, as for example: A man is running a freight train and wants to get home to meet his girl or wife. He is going to some park or show or dance and is anxious to get there a little bit ahead of time. In order to do it, he sneaks in on some passenger train's time when the rule says he must clear the passenger train ten minutes. He may do this twelve times and nothing happens, and then the thirteenth time —that unlucky number—a collision occurs and you know who gets "canned." It is not the train dispatcher, who has known of his doing it the other twelve times and said nothing.

I will illustrate this chance theory by telling you something I saw in a paper, taken from an article read by the Attorney-General from Missouri, showing the number of murders committed in this country in proportion to those committed in the old country. In Germany, where they enforce the law (we don't do it here any more than we enforce rules on the railroad) they have four murders annually for every million people. In the United States, where we don't enforce the laws, we have 129 murders for every million people. In Germany, where they enforce the rules for operating railroads, they have less than one half the fatalities to employees that we have in the United States in proportion to the number of men employed, because they obey the rules and because they remember that it is better to cause a delay than it is to cause an accident.

The management of the Chicago & Northwestern Railway, being both far-sighted and humane, recognized, perhaps earlier than most other employers of labor, the great suffering that was caused by avoidable accidents resulting in death and injury to its men, passengers and others; and because of that as well as for the further reason that, during the year ending June 30th, 1910, our accidents resulting in the deaths to employees increased 37 per cent, to passengers 38 per cent and to outsiders 19 per cent, and injuries had increased 27, 38 and 12 per cent, respectively, we determined about two years ago to inaugurate a movement to reduce such accidents, both as a matter of humanity and for the purpose of increasing the efficiency of its organization, as every time a capable, experienced employee was killed or injured it not only brought suffering and sorrow to himself and family, but necessitated the employing of a new man in his place, thereby increasing the risk to the other men in the service and at the same time decreasing the efficiency of the organization, frequently very seriously.

For example: Take from the service for ten days the foreman at a roundhouse, the train master, the superintendent, the section foreman, the roadmaster, the brakeman or conductor or the engineer and fireman on some special job or some special train, and put a green man in his place, and we all know that unless we happen to get some extraordinarily experienced competent man, it will not only increase the risk to the men left on the trains, to everybody in the shops or the roundhouse or on the tracks, but it will at the same time decrease the efficiency of the organization which goes down accordingly.

As a concrete example take the case of an employee killed on our elevated tracks. The man killed was foreman of a switch engine which was coming from Wood Street to Fortieth Street. On the way over he met another engine which was stalled with a train. At the request of the crew of the stalled train he coupled on his engine and pulled them over to Fortieth Street. When he got there he uncoupled his engine and sent it ahead, then started to walk over to it. The engine which he had assisted over from Wood Street started up without ringing the bell, ran over and killed him. Rules No. 30 and 26 require that bells shall be rung when an engine is about to move and while switching on the elevated tracks, and certainly when an engine has been standing and has started up, whether it is on elevated tracks or on tracks at grade, the bell should be rung to give notice that it is about to be moved. If that had been done in this case a man's life would probably have been saved, and a widow and three or four children would not have been left in mourning, destitution and misery. And think how much less time it would have taken to start that bell than it did to make a report of the accident, and how much it increased the risk to the rest of the men to have such a man taken out of the service and the man who caused his death left in the service.

The work of organizing and directing this movement was assigned to me, and I was glad it was, because it seemed to me that the knowledge and experience I had gained in the investigation and settlement of accident claims ought to be of some benefit to the men on the road that I had grown up with, and that with proper effort and co-operation might aid largely in reducing the number of deaths and injuries to our employees; and if you operating men could have seen a small part of the procession of widows and orphans, dependent fathers and mothers and cripples that have passed through my office during the last thirty years, you would have realized more than you now do the necessity of the adoption of some practical plan to bring about better and safer working conditions.

Believing that only through the active co-operation and assistance of the men who were being injured could any plan for the prevention of accidents be made a success, and that if the men could be made to understand the matter right, their coöperation and assistance could be secured, I undertook to organize the movement on the basis of making them the controlling factor in the work,

* Extracts from an address at the annual meeting of the General Managers' Association of the Southeast, at Atlanta, Ga., June 13th, 1912, by Ralph C. Richards, chairman Central Safety Committee, Chicago and Northwestern Railway.

We commenced by holding meetings on all the seventeen divisions of the system, first of the division officers and foremen, and afterward of the men, and explained what we were trying to do and its necessity: that it was the men and not the stockholders, officers or foremen who were being killed and injured and paying the fearful toll in death and injury; that it was the men and their families who would be most benefited by the prevention of accidents; that the golden rule in railroading—"It is better to cause delay than to cause an accident"—should be observed.

We also tried to impress upon them: That it actually took less time to prevent an accident than it did to report one. That when we needed new men, if we had 50 per cent fewer accidents on our road than other lines had, we would have the pick of all the best railroad men in the country; wages and other working conditions being practically the same on all railroads, all the good men would want to work on the railroad where there was the smallest risk of being killed or injured. That it was the little accidents that make up the big total, just as it is the little things that count everywhere. That on our road twelve out of thirteen employees were killed in the little accidents and 33 out of 34 injured in the little accidents, the other one killed and injured being in big, or train accidents, such as collisions and derailments. That consequently it was the little accidents we wanted to get rid of and the big ones would take care of themselves. That we wanted to get rid of the careless habit and acquire the safety habit. That we wanted to stop making cripples, widows and orphans. That the greatest risk a careful man runs is of injury from some careless fellow-worker, and that when the careless man will not change his ways and try to do better he should be gotten out of the service. That it takes less time to learn to do a thing right than to explain why you did it wrong. That the exercise of care to prevent accidents was a duty which each employee owed to himself and his fellow-employees. That every accident is a notice that something is wrong with the man, plant or methods, and should be immediately investigated by the person in charge of work to ascertain the cause and apply a remedy. That each employee was responsible for the safety of others as well as himself. That in case of doubt, adopt the safe course; speed must always give way to safety. That if we could reduce the accidents 50 per cent, the assessments for life and accident insurance which the men are paying ought to be reduced in the same proportion. That it was better to be careful than crippled.

Safety committees were then organized on each division of the road, composed of the three division officers and one or more representatives from each class of labor, such as engineers, firemen, conductors, brakemen, switchmen, track men, station men, bridge men and car men. The same committees were organized in the large terminal yard, the members being yardmasters, switchmen, engineers, firemen, track men and car men. In the shops committees were also organized, composed of all classes of labor, always the men who were doing the work and getting hurt (not the bosses) being the large majority of the membership. These committees meet once each month. The men serve not less than six months nor more than twelve and are paid for their time and expenses while attending meetings.

Then the central safety committee was organized, composed of ten general and division officers, representing all branches of the service, of which committee I am the chariman, and to which committee all division, shop and yard committees report and to whom all changes in standards, rules and customs are submitted and, if approved, are referred to the management for adoption. All matters local to the divisions, shops and yards are disposed of by such committees without reference to the central safety committee, but the recommendation made and action taken is reported.

During the first year of this organization 5,619 different subjects were brought to the attention of these committees and acted upon. Every member of the committee is furnished with a safety button as his badge of office and is made to feel that in the meetings all men are on a par, and each comes there as a committeeman, not as an officer or employee, and that all are full partners in the enterprise and responsible for its success. Suggestions that might bring about greater safety and efficiency in operation were not only invited but solicited. Postal cards were furnished to the members of the committees and employees generally, on which immediate notice could be given to the chairman of the division committee of dangerous conditions and practices, so that the same could be remedied immediately and not wait for the meeting. Trips of inspection were made over the various divisions on special trains for the purpose of demonstrating to the members that a real inspection to find defects was desired, and for the purpose of advertising the committee to all the employees, as well as for the purpose of getting in closer touch with the members. Each division, shop and yard committee is furnished with enough copies of all the proceedings of the central safety committee so that each member will know what is done, not only with their recommendations, but also with the recommendations made by all the other committees. They are also furnished with detailed report of all accidents by divisions, statements of accidents by cause, and a statement of avoidable accidents that happened the previous month. Slips are put on pay checks of all employees each month calling attention to specific acts of carelessness, to rules or other things that may cause or prevent accidents, a different one being gotten up for each month, so as to avoid sameness and repetition.

After the work was well under way, it was decided to award a banner to the division having the fewest accidents in proportion to the number of employees and its train mileage, and the central safety committee awarded that banner to the Sioux City division in 1911, and to the Wisconsin division in 1912. I believe that it is the first time that such an award has been made in the history of railroading in this or any other country. A similar banner was presented to the North Avenue yards for the best record for safety in 1911.

On a railroad 8,000 miles long, running through nine States, it necessarily took some time and considerable work to lay the foundation for such an organization and to get it properly started, but on January 1st, 1911, our organization was practically completed.

We also adopted a plan of writing letters of commendation of individual and collective efforts to bring about greater safety, which could be posted on the bulletin boards or shown to the members of the committees or other employees, and letters to division officers calling attention to certain specific accidents, in order that steps might be taken to warn the men, and thus prevent their recurrence.

There are now about 590 officers and men serving on these safety committees and, if Benjamin Franklin's saying, "The eyes of the master can do more work than both of his hands," is true, surely 590 pairs of eyes trained to look for defective conditions and practices can do more than the eyes of one person, of fifty persons, and from the results that have been attained during the first seventeen months that the safety organization has been in existence (during which time the earnings of the company decreased about 6 per cent) we have shown a very gratifying improvement in the matter of cleaning up obstructions in yards, station platforms, shops and roundhouses, cleaning windows, putting up railings at dangerous places, covering gearing of machines, blocking frogs and guard rails, in putting a stop to dangerous practices and customs and in repairing cars, engines and machines, which has not only brought about greater safety, but also more efficient operation.

We also show the following reduction in our accident record, as compared with the last seventeen months, prior to the organization of the safety committees. In this statement all cases of injury where a man loses one day's time or more are counted, whereas, in the reports made to the Interstate Commerce Commission and railroad commissions generally, we report only the cases where the injured employee loses three days' time or more:

1911-12	1909-10	Per cent.
26 fewer trainmen killed	a decrease of	50.0
2012 fewer trainmen injured	a decrease of	43.9
11 fewer switchmen killed	a decrease of	44.0
171 fewer switchmen injured	a decrease of	18.7
3 fewer station men killed	a decrease of	50.0
211 fewer station men injured	a decrease of	21.1
1122 fewer track men injured	a decrease of	44.1
152 fewer bridge men injured	a decrease of	32.8
5 fewer car repairers killed	a decrease of	62.5
45 fewer car repairers injured	a decrease of	10.4
274 fewer shop and R. H. men injured	a decrease of	14.8
1 fewer other employees killed	a decrease of	7.1
19 fewer other employees injured	a decrease of	4.3

4 bridge men killed in 1911-12, same as 1909-10.
7 shop and roundhouse men killed in 1911-12 and 1909-10.
But an increase of three track men killed in 1911-12.

Total Reduction of

		Per cent.
43 fewer employees killed	a decrease of	29.0
4006 fewer employees injured	a decrease of	32.8
8 fewer passengers killed	a decrease of	38.1
204 fewer passengers injured	a decrease of	17.0
73 fewer other persons killed	a decrease of	23.0
132 fewer other persons injured	a decrease of	15.4

Total.

124 fewer persons killed	a decrease of	25.4
4342 fewer persons injured	a decrease of	30.4

	1911-1912		1909-1910	
	Killed	Injured	Killed	Injured
Employees	106	8215	149	12221
Passengers	13	993	21	1197
Other persons	244	724	317	856
Total	363	9932	487	14274

In connection with the reduction of accidents, I desire to call attention to the large decrease which we have had in the number of trainmen killed and injured during the five months ending May 31st, 1912, as compared with the five months ending May 31st, 1910, before the safety movement was inaugurated. In 1910 we had sixteen trainmen killed and 1,461 injured. In 1912 we had nine killed and 695 injured, a decrease in the killed of seven and injured 766.

This reduction seems to me to be a little remarkable in view of the unusual severity of the weather which we experienced during the first three months in 1912. I do not believe that in the history of the Northwestern railroad, we have had any consecutive months where weather conditions were so hard on the men and the machines, as they were in January, February and March and nearly all of April, 1912.

This not only means that in the last seventeen months we have had 124 fewer paper reports of people killed, and 4,342 fewer paper reports of people injured than we had during the preceding seventeen months, but that 124 fewer times did we have to call the priest and the undertaker; that 124 fewer times were widows and orphans made and sorrow and sometimes destitution brought into families; that 4,344 fewer times was someone injured, often permanently; that just that many fewer times did we have to call the doctor and that in our own railroad family 4,055 times did we avoid increasing the risk to other employees, our passengers and patrons by taking experienced men out of the service and putting green ones in their places, and that just that many fewer times did we avoid decreasing the efficiency of our organization.

This result has been obtained because we learned that accidents were not inevitable, as we had commenced to believe, but, on the contrary, a large proportion of them could be avoided by the exercise of care, and because we have all worked in harmony to bring about an improvement. If the first seventeen months' work is an indication of what we can do in the future, it would certainly seem to show that the plan which we have adopted, in which enthusiasm and co-operation for safety is the keynote, will surely result as the years go by in greater safety and regularity, which is what we all want.

(To be continued.)

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